ETI for Electronics & Computing Enthusiasts

$2.25
MM70924

Circuits Feature: Instrumentation Techniques

Electronics Today
INTERNATIONAL

June 1983

Polyphonic Touch Organ
PROJECT

Play and conduct!

Outdoor PA
The hills are alive . . .

Overload Indicator
PROJECT

Audio clipping detector

Saturn up close
Voyage to the rings

TRS-80 Model 100
Tested

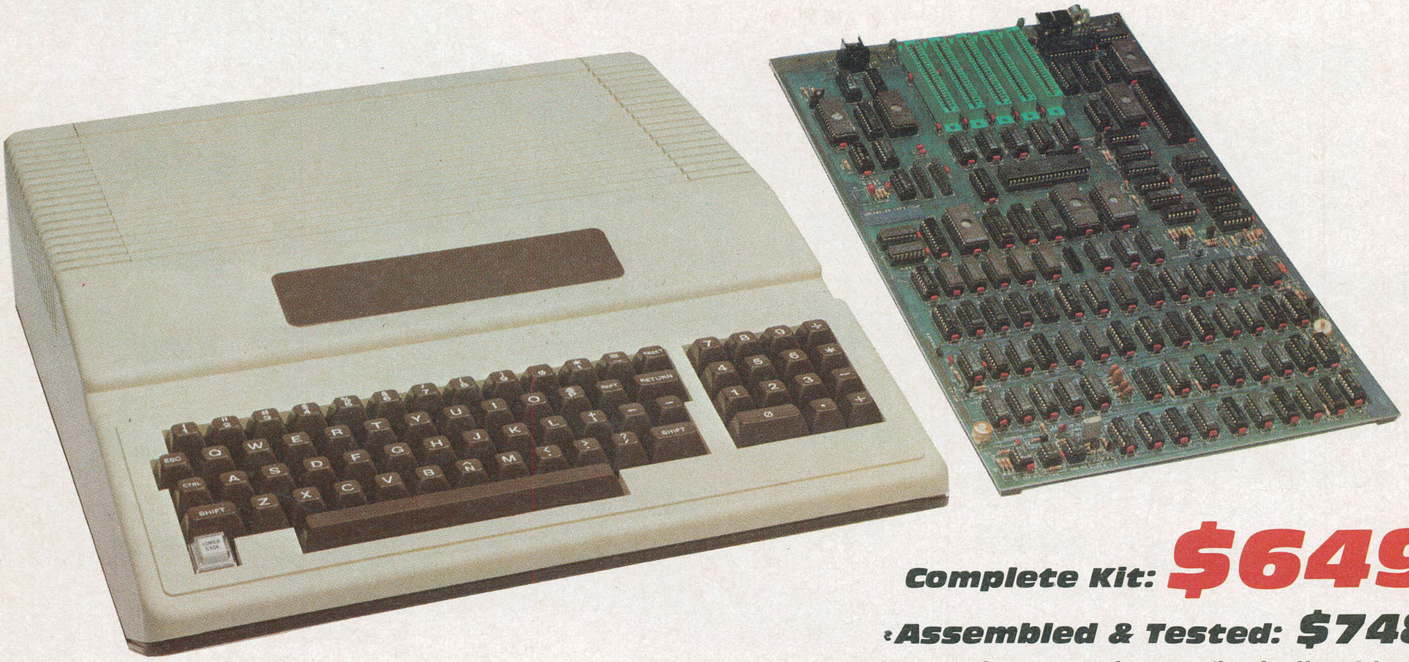
0 57438 70924 06

SURPLUSTRONICS

we will not be undersold

6502 System

(Kit)



Complete Kit: $649

Assembled & Tested: $748

Includes PCB, complete set of parts (including blank EPROMS) power supply, case, keyboard and blank Z80 card PCB.

"This could well be the best value in computers offered at any time, anywhere in the world."

This 6502 board is a vast improvement on others available:

- 64K RAM (8-4164 chips)
- 80 x 24 video included on board
- Floppy Disk Controller included
- FIVE additional slots
- Z80 blank PCB included
- Powerful power supply (5V 5A, +12V 2 up to 3A peak, −5V 0.5A, −12V 0.5A)
- Superb quality plastic case
- Excellent keyboard including numeric keypad
- EPROMS (blank) included
- Full service facilities: normal maximum charge $50 on properly assembled kits as described in our service pamphlets.

As Reviewed in ETI May 1983

This board in all honesty far exceeds our original expectations and demand is spectacular. This board will also fit the older/cheaper cases and keyboards.

Mail Orders add $3.00 for handling. Ontario residents add 7% P.S.T. Visa, Mastercard and American Express cards accepted: send card number, expiry data, name of bank and signature. Send certified cheque or money order, do not send cash.

Optional Extras

5¼" Disk Drives

Attractively packaged, ready to plug in. Extremely reliable. **$299**

12" Zenith Monitor

Ready to use; switchable for 40 or 80 characters. 90 day warranty. **$137**

Parts for Z80 Card

Fills up the supplied PCB; enables you to run CP/M software. **$69**

PCB only $57
Parts Complete $255
Gemini 10 printer $499

Surplustronics, 310 College Street, Toronto, Ontario, M5T 1S3 (416) 925-8603.

Circle No. 22 on Reader Service Card.

The Magazine for Electronics & Computing Enthusiasts

Electronics Today INTERNATIONAL

June 1983
Vol. 7 No. 6
ISSN 0703-8984

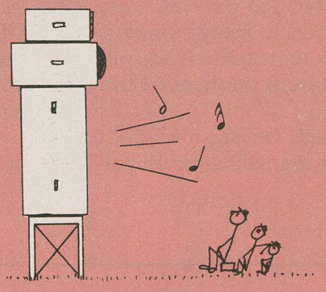
Member ABC Audit Bureau of Circulations

Features

Projects

Our Cover

The Polyphonic Touch Organ, still under construction, nestles with some acoustic friends; see page 15. The TRS-80 Model 100 is reviewed on page 39. Photos by Steve Rimmer.



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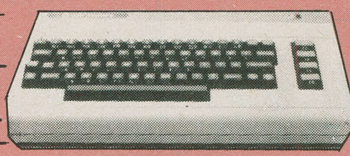

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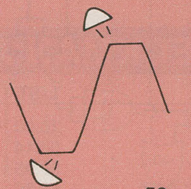

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Columns, News and Information

ADVERTISERS' INDEX

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We can supply photocopies of any article published in ETI Canada; the charge is $2.00 per article, regardless of length. Please specify both issue and article.

COMPONENT NOTATION AND UNITS
We normally specify components using an international standard. Many readers will be unfamiliar with this but it's simple, less likely to lead to error and will be widely used everywhere sooner or later. ETI has opted for sooner!
Firstly decimal points are dropped and substituted with the multiplier: thus 4.7uF is written 4u7. Capacitors also use the multiplier nano (one nanofarad is 1000pF). Thus 0.1uF is 100nF, 5600pF is 5n6. Other examples are 5.6pF = 5p6 and 0.5pF = 0p5.
Resistors are treated similarly: 1.8Mohms is 1M8, 56kohms is the same, 4.7kohms is 4k7, 100ohms is 100R and 5.6ohms is 5R6.

PCB Suppliers
ETI magazine does NOT supply PCBs or kits but we do issue manufacturing permits for companies to manufacture boards and kits to our designs. Contact the following companies when ordering boards.
Please note we do not keep track of what is available from who so please don't contact us for information on PCBs and kits. Similarly do not ask PCB suppliers for help with projects.

K.S.K. Associates, P.O. Box 266, Milton, Ont. L9T 4N9.
B—C—D Electronics, P.O. Box 6326, Hamilton, Ont., L9C 6L9.
Wentworth Electronics, R.R.No.1, Waterdown,Ont., L0R 2H0.
Danocinths Inc., P.O. Box 261, Westland MI 48185, USA.
Arkon Electronics Ltd., 409 Queen Street W., Toronto, Ont., M5V 2A5.
Beyer & Martin Electronic Ltd., 2 Jodi Ave., Unit C, Downsview, Ontario M3N 1H1.
Spectrum Electronics, 14 Knightswood Crescent, Brantford, Ontario M3R 7E6.

POSTAL INFORMATION
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- 0.25% Vdc accuracy
- 10 Amp ac,dc current

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Model 3020B
- Audible and visual continuity indicator
- 0.1% Vdc accuracy

$271

Model 3010UL
- Insta-ohms® continuity indicator
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HD-100 SERIES
- Drop-proof
- Contamination-proof
- Shockproof

Model RMS 3030
- True RMS measurement
- 0.1% Vdc accuracy

$315

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- 0.1% Vdc accuracy
- 10 Amp ac/dc current
- Audible and visual continuity indicator
- .01Ω resolution on 20Ω range

$326

Model 3060
Same features as 3050 plus:
- True RMS measurement
- Direct temperature measurement

$424

The special features of Beckman's nine models satisfy the needs of all applications from laboratory use to adverse industrial environments. All Beckman models are easy to use and reliable because of the single rotary switch and a custom CMOS LSI chip which eliminates most discrete components found in other DMMs. One-hundred percent burn-in and complete computer testing insure consistent reliability.

COMMON FEATURES FOR ALL MODELS

- 2,000 hour battery life with standard 9V battery
- 2 amps ac/dc current ranges
- 22MΩ Vdc input impedance
- Superior RF shielding
- Separate "high power" diode test function
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- 100% factory checkout
- Large LCD display

DESCRIPTION
WITH ADDITIONAL FEATURES

Model 3000: 3½-digit multimeter; 0.25% Vdc accuracy
Model 3010: 3½-digit multimeter; 0.25% Vdc accuracy, 10 amps ac and dc ranges, Visual Continuity Indicator
Model 3010UL: 3½-digit multimeter; 0.25% Vdc accuracy, 10 amps ac and dc ranges, Visual Continuity Indicator, Underwriters Laboratories® listed
Model 3020: 3½-digit multimeter; 0.1% Vdc accuracy, 10 amps ac and dc ranges, Visual Continuity Indicator
Model 3020B: 3½-digit multimeter; 0.1% Vdc accuracy, 10 amps ac and dc ranges, Audible/Visual Continuity Indicator
Model RMS 3030: 3½-digit multimeter; True RMS, 0.1% Vdc accuracy, 10 amps ac and dc ranges, Visual Continuity Indicator
Model 3050: Bench/Portable 3½-digit multimeter; 0.1% Vdc accuracy, 10 amps ac and dc ranges, Audible/Visual Continuity Indicator, 0.20 ohms, 4 year battery life
Model RMS 3060: Bench/Portable 3½-digit multimeter; True RMS, 0.1% Vdc accuracy, Temperature Measuring Capability, 10 amps ac and dc ranges, Audible/Visual Continuity Indicator, 0-20 ohms, 4 year battery life
HD-100: Heavy Duty 3½-digit industrial multimeter; 0.25% Vdc accuracy, contamination-proof, drop-proof, high overload protecton, Visual Continuity Indicator
HD-110: Heavy Duty 3½-digit industrial multimeter; 0.25% Vdc accuracy, 10 amps ac and dc ranges, contamination-proof, drop-proof, high overload protection, Visual Continuity Indicator.

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MODEL	DESCRIPTION	LIST
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DC-206	Deluxe Bench Meter Carrying Case (3)	59.95
HV-211	High Voltage Probe-50KV DC Maximum (1,2&3)	82.30
RF-221	RF Probe - 2KHZ-200MHZ (1,2&3)	68.13
CT-231	AC Current Transformer - 10-150 Amps (1,2&3)	108.46
CT-232	AC Current Transformer - 10-1000 Amps (1,2&3)	256.15
DL-241	Deluxe Test Lead Kit (1)	19.62
TL-242	Spare Test Leads (1)	9.81
DL-243	Deluxe Test Lead Kit (2&3)	19.62
TL-245	Spare Test Leads (2&3)	11.99
TP-254	Thermocouple Temperature Probe K-type nickel chromium/nickel aluminum (4)	71.94
TP-255	K-type Thermocouple, four foot leads (4)	16.90
TC-253	Temperature/Voltage Converter, C or F (1&2)	93.74
FP-260	Multimeter Fuses, 2A/600V, packet of 4 (1&2)	3.65

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Circle No. 10 on Reader Service Card.

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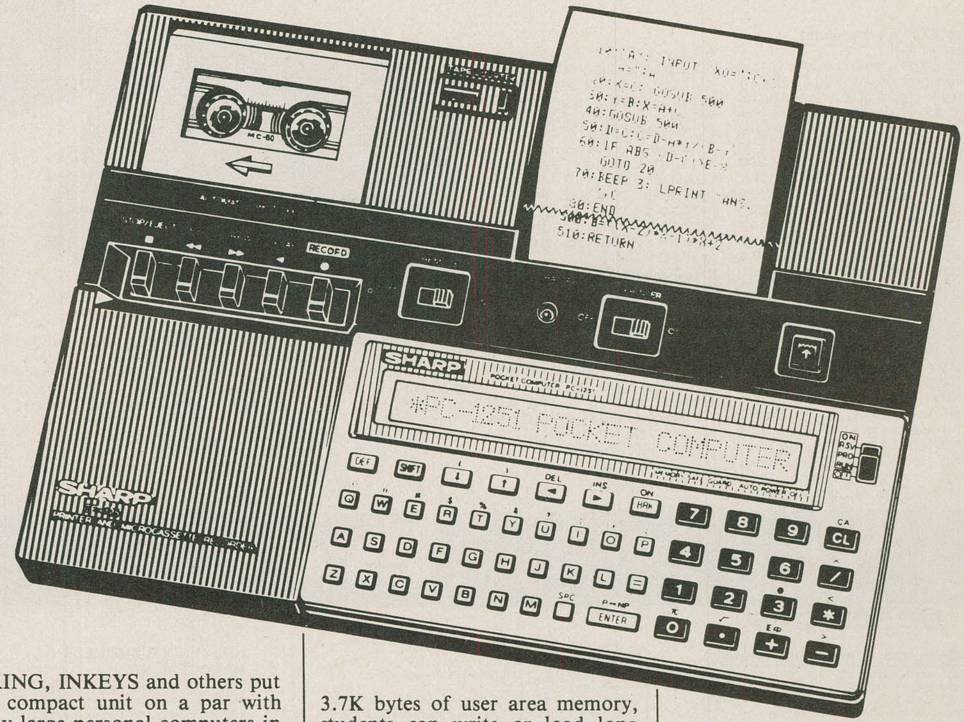

New Sharp Computer

The SHARP PC-1251 provides students and other first-time computer users with a low cost yet powerful computer system in a four-ounce package.

No larger than many desk-top calculators, the PC-1251 uses extended BASIC programming, with commands and statements that are designed for easy programming in a wide range of applications. DIM, STRING, INKEYS and others put this compact unit on a par with many large personal computers in terms of programming performance.

With 24K bytes of ROM and 4.2K bytes of RAM, including 3.7K bytes of user area memory, students can write or load long programs for a variety of applications.

Available from Sharp Electronics computer dealers or from select retail stores across Canada, the PC-1251 offers a 24-digit dot matrix display and a reverse/program/run mode selector.

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LIABILITY
While every effort has been made to ensure that all constructional projects referred to in this magazine will operate as indicated efficiently and properly and that all necessary components are available, no responsibility whatsoever is accepted in respect of the failure for any reason at all of the project to operate efficiently or at all whether due to any fault in the design or otherwise and no responsibility is accepted for the failure to obtain component parts in respect of any such project. Further no responsibility is accepted in respect of any injury or damage caused by any fault in design of any such project as aforesaid.

Editorial Queries
Written queries can only be answered when accompanied by a self-addressed, stamped envelope. These must relate to recent articles and not involve the staff in any research. Mark such letters ETI-Query. We cannot answer telephone queries.

Hi-Fi VCR Audio

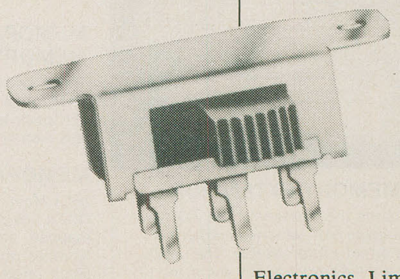
By mid-1983, Sony of Canada will introduce their new SL-5200 video cassette recorder featuring substantially improved stereo sound. The usual method of recording the soundtrack has been to use a narrow longitudinal track running at tape speed. The slow speed and narrow width made for poor sound quality. Sony has now FM encoded the soundtrack in between the luminance and chrominance signals, and it is recovered by the rapidly rotating head. Specifications are said to be a dynamic range of better than 80 dB, distortion less than 0.3%, and wow and flutter of less than 0.005%.

Low Profile Slide Switches

A series of Switchcraft slide switches with the knob actuator on the side rather than conventional top position offers especially low profile space savings on PC boards. Along with space savings, Series 62000 Slide Switches feature reliable 2-position, 2-C (DPDT) locking action. PC terminals, located on .181-inch by .272-inch centers, are offered with or without mounting ears.

A variety of side knob actuator lengths are available on special order. New switches have a current rating of 0.5 amps; 125 V AC or DC.

Switchcraft Products are represented in Canada by Atlas Electronics Limited, 50 Wingold Avenue, Toronto, Ontario, with branch offices in Montreal, Ottawa, Winnipeg, Calgary, and Vancouver.



ORION ELECTRONICS . . . . . COMPUTER ROOM . . . . . ORION ELECTRONICS . . . . . COMPUTER ROOM

Sinclair ZX81 Computer Etc . . .

Assembled $99.95

ZX81

The ZX81's advanced capability.
The ZX81 uses the same fast microprocessor (Z80A), but incorporates a new, more powerful 8K BASIC ROM — the "trained intelligence" of the computer. This chip works in decimals, handles logs and trig, allows you to plot graphs, and builds up animated displays. And the ZX81 incorporates other operation refinements — the facility to load and save named programs on cassette, or to select a program off a cassette through the keyboard.

New, improved specification.
*Unique 'one-touch' key word entry: eliminates a great deal of tiresome typing. Key words (PRINT, LIST, RUN, etc.) have their own single-key entry. *Unique syntax-check and report codes identify programming errors immediately. *Full range of mathematical and scientific functions accurate to eight decimal places. *Graph-drawing and animated-display facilities. *Multi-dimensional string and numeric arrays. *Up to 26 FOR/NEXT loops. *Randomize function. *Programmable in machine code. *Cassette LOAD and SAVE with named programs. *1K-byte RAM expandable to 16K. *Full editing facilities. *Able to drive the new Sinclair ZX Printer (to be available shortly).

If you own a ZX80. . .
The new 8K BASIC ROM as used in the ZX81 is available as a drop-in replacement chip. (Complete with new keyboard template and operating manual). With the exception of animated graphics, all the advanced features of the ZX81 are now available on your ZX80 — including the ability to drive the Sinclair ZX Printer.

16K Memory Expansion Kit (No P.C. Board) **$49.00**

Sinclair's new 8K Extended Basic offers features found only on computers costing three or four times as much. *Continuous display, including moving graphics. *Multi-dimensional string and numerical arrays. *Math and scientific functions accurate to 8 decimals. *Unique one touch entry of "key words" (i.e. basic and system commands). *Automatic syntax error detection. *Randomize function. *Built-in interface for ZX Printer. *Connects to standard TV and cassette recorder. *164 page manual included. *Power supply (9V at 650 ma) optional for $14.95. *1K of memory is included.

$149.00

Designed exclusively for use with the ZX81 (and ZX80 with 8K basic ROM), the printer offers full alphanumerics and highly sophisticated graphics. COPY command prints out exactly what is on screen. At last you can have a hard copy of your program listing and results. Printing speed is 50 characters per second, with 32 characters per line and 9 lines per vertical inch. Connects to rear of ZX81 — using a stackable connector so you can use a RAM pack as well. A 65 ft paper roll, instructions included. Requires 9 volts, 1.2 amp power supply (option extra).

Machine Language Software

ZXAS Machine Code Assembler. A full specification Z80 assembler. Standard mnenonics are written directly into your BASIC program **$19.00**

ZXDB Disassembler/Debugger. Perfect complement to ZXAS, also provides single step, string search, block transfer, hex loader. **$19.00**

Etc . . .

Software

GAMES (Arcade, Adventure, Strategy)

KRAKIT - Win $20,000	$24.95
1K GAMES PACK - II games for 1K ZX81	13.95
GOBBLEMAN - Famous arcade game.	19.95
ZX GALAXIA - SYNC said this ZX81 version was the best	19.95
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ZX CHESS I (Master-16K)	19.95
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PROGRAMMERS AIDS & LANGUAGES

ZX ASSEMBLER - Two pass assembler for MC programs	19.00
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ZX FORTH - 56 pg manual enhances this language	39.95
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*TM

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***All Mathematics series includes two tapes, holder & workbook.**

ADDITIONAL SOFTWARE FOR SINCLAIR AVAILABLE.

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COMPLETE ZX81 BASIC COURSE - inc. 2 tapes	39.95
NOT ONLY 30 PROGRAMS: 1K	16.95
MACHINE LANGUAGE MADE SIMPLE	19.95
ZX81 ROM DISASSEMBLY PART A & PART B	24.95
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EXPLORERS GUIDE TO THE ZX81	16.95
ZX81 POCKET BOOK	16.95
GETAWAY GUIDE	16.95
GETTING AQUAINTED WITH YOUR ZX81	16.95

Hardware

ZX81 Ass.	99.95
ZX Print	149.00
64K - RAM (Memotech)	249.95
32K RAM (Memotech)	179.00
16K RAM (Memotech)	89.00
16K RAM (Sinclair)	59.00
16K RAM (Kit no PC board)	49.00
Power Supply (650 M.A.)	14.95
Power Supply (1 AMP)	19.95
Keyboard (uncased) - 47 Keys, Assembled no soldering req.	119.95
Metal Case for above	29.95
Memopak High Res. Graphics Pack	199.95
Memopak Centronics Type Parallel Printer Interface	159.95

*** Interface for any serial printer & 4 cassette recorders; includes plugs, cords and a detailed manual.**

Memopak...

MEMOPAK 32K $179.00 and 16K $89.00 MEMORY EXTENSIONS

These two packs extend and complete the Memotech RAM range (for the time being!) A notable feature of the 32K pack is that it will run in tandem with the Sinclair 16K memory extension to give 48K RAM total.

MEMOPAK 64K MEMORY EXTENSION

The 64K Memopak extends the memory of the ZX81 by 56K, and with the ZX81 gives 64K, which is neither switched nor paged and is directly addressable. The unit is user transparent and accepts commands such as 10 DIM A(9000).

Breakdown of memory areas ... 0-8K Sinclair ROM. 8-16K-This area can be used to hold machine code for communication between programmes or peripherals. 16-64K-A straight 48K for normal BASIC use. **$249.95**

MEMOPAK HIGH RES GRAPHICS PACK

HRG Main Features — ● Fully programmable Hi-Res (192 x 248 pixels) ● Video page is both memory and bit mapped and can be located anywhere in RAM ● Number of Video pages is limited only by RAM size (each takes about 6.5K RAM) ● Instant inverse video on/off gives flashing characters ● Video pages can be superimposed ● Video page access is similar to Basic plot/unplot commands ● Contains 2K EPROM monitor with full range of graphics subroutines controlled by machine code or USR function **$199.95**

MEMOPAK CENTRONICS TYPE PARALLEL PRINTER INTERFACE

Main Features — ● Interfaces ZX81 and parallel printers of the Centronics type ● Enables use of a range of dot matrix and daisy wheel printers with ZX81 ● Compatible with ZX81 Basic, prints from LLIST, LPRINT and COPY ● Contains firmware to convert ZX81 characters to ASCII code ● Gives lower-case characters from ZX81 inverse character set **$159.95**

POWER SUPPLY	**500ma**	**$14.95**
POWER SUPPLY	**1A**	**$19.95 (FOR PRINTER)**

Orion Electronic Supplies Inc.
40 Lancaster Street West
Kitchener, Ontario N2H 4S9
(519) 576-9902

Master Charge & Visa, COD, Cheque, Money Orders accepted. COD's, shipping & insurance extra. Write for our FREE FLYER.

Prices subject to change without notice.

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EXPANDER $1775.00

Disc Controller Card up to four Double sided, Double Density Disc Drive $475.00

SPECIFICATIONS

PHYSICAL

- Dimensions: 17½" Wide. 4½" High. 16¾" Deep.
- Shipping Weight: 32lbs.

DISPLAY CHARACTERISTICS

- Black and white mode 24 x 80 character display.
- 128 character upper/lower case including control keys.
- Option: expandable to 256 charcters.
- Black/white graphics resolution 160 horizontal x 72 vertical.
- Color graphics resolution 80 x 72.
- 64 colors, each with 4 intensities for a total of 256 colors.
- Simultaneous use of all colors
- 40 characters x 24 lines in color mode
- Video output standard NTSC televison compatible.

INTERFACE

- RS-232 Serial Interface
- Centronic-style parallel interface for I/O.

KEYBOARD

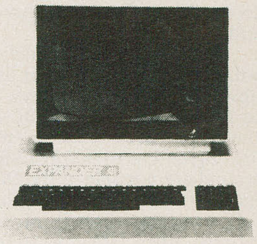
- 80-key layout.
- 62-key typewriter style
- 18-key numeric calculator-style keypad.
- Auto repeat
- User-selectable for 4 function keys.
- 4 cursor keys

GENERAL OPERATING FEATURES

- Z80 A (3.58 MHz) CPU
- 64K RAM memory.
- S-100 bus (IEEE-696)
- 4 slots for expansion
- Real-time clock programmable for 64 msec. to 4 mil. sec.
- Interrupt driven keyboard, real-time clock, serial port and cassette interfaces.
- 5 additional prioritized interrupts available
- Addressable up to 16 mBytes using bank switching.

SOFTWARE

- CP/M compatible
- 4K ROM Monitor with commands for loading and saving on cassette to and from memory and for program execution.
- Runs on any Z80-based CP/M compatible applications software.



A PROFESSIONAL COMPUTER
for the price of a personal computer

At last, a professional computer that doesn't cost more than a personal computer. It's called the Expander, and it's easy for beginners to understand, yet capable of the most complex tasks for your business needs. As a business computer, the Expander can also be used as a word processor, can display graphics in 256 colors, and handle numerous program languages. The Expander accommodates many existing peripherals, making it the most flexible professional computer on the market today . . . and all for the price of a personal computer. The Expander may well be exactly what you are looking for in a computer, but, until now, you haven't been able to find.

EXPANDER CAN BE USED FOR WORD PROCESSING
The Expander also works as a word processor, with a high quality typewriter-style keyboard. Any experienced typist will feel comfortable with the Expander. It's as simple as working with an ordinary typewriter! There are several different word processing programs available for use with the Expander.

EXPANDER DISPLAYS GRAPHICS IN 256 COLORS
The Expander can display your graphics in any or all of 256 colors, all selectable in either BASIC or the system monitor, making it easy for a programmer who wants graphics in many colors. S-100 boards are also available to plug into your Expander for very high-resolution graphic needs.

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The Expander can help you with all your business needs: Speed up customer service. Avoid hiring extra clerical help. Set up close inventory controls. Produce accurate, timely and complete management reports. Make billing easier. Monitor receivables and payables. Tap underdeveloped profit centers. Free staff from routine tasks for more important jobs. The Expander can help you make dramatic improvements in all these areas!

EXPANDER COMPATIBLE WITH MANY PERIPHERALS
The Expander is a S-100 (IEEE-696) compatible computer, and gives you the widest choice of boards and peripherals available. As a result, the Expander can be used for many applications not previously considered for small computers. For example, controlling very large inventories, communicating intensively with other computers, and monitoring a sophisticated burglar alarm or heating/air conditioning system in several different locations.

EXPANDER CAN USE MANY LANGUAGES
The Expander can use many different program languages: BASIC, PASCAL, FORTRAN, COBOL, APL, ALGOL, C, MACRO and many more that run under CP/M format. If you use a special program language, the Expander is likely to fit your needs.

EXPANDER IS EASY TO UNDERSTAND
The Expander has been designed for easy use, because a computer is only as useful as your ability to understand it. The Expander is very easy to understand, with an easy-to-read instruction book. You will start learning how to program in BASIC within 10 minutes. Try it for yourself. You'll be surprised!

EXPANDER DOESN'T NEED A TERMINAL
The Expander, unlike other more expensive professional computers, doesn't need a separate terminal. This gives you important advantages: faster operation, less cost, and less space.

EXPANDER AND ALL THIS
High quality typewriter-style keyboard. Built-in separate calculator keypad. 2 user-programmable function keys w/4 functions. 4 cursor control keys. Screen format: 80 Characters/line-24 lines. Characters in both upper and lower case. 4K ROM operating system. 64K RAM memory. Parallel printer interface (industry standard). S-100 Bus (IEEE-696) w/4 slots. CP/M compatibility. Z80 A processor (3.58 MHz). Real-time clock. RS-232 Serial interface. Cassette tape interface. Video output & color graphics in 256 colors. Complex-tone generator w/internal speaker. Expandable to 512K of memory!

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AMB-1 $399.50
Mother Board, APPLE II Compatible, Assembled & Tested c/w Basic ROMS, 48K RAM, Made in Japan

ABB-1 $ 45.00
APPLE II Compatible, Motherboard (no components)

6502 Board Kit $275.00
Includes all parts

PDA-232C $149.00
Serial interface RS232C Card for APPLE II c/w Cable & Manual, Three Operating Modes: I/O, Terminal, Remote

AEB-1 $149.00
EPROM Burner Card

AIC-1 $129.00
Integer Card

AEC-1 $149.00
80 Column Card

AZC-1 $149.00
Z80A (CPM) Card

APC-1 $129.00
Parallel Printer Card

ASC-1 $129.00
Serial Printer Card

ALC-1 $99.00
16K RAM (Language) Card

AGC-1 $219.00
Graphics Parallel Printer Card

AKB-1 $109.95
Keyboard; replacement for APPLE II

AC-1 $85.00
Beige APPLE II Case (No keyboard)

APS-1 $ 99.00
Switching Power Supply for APPLE II; +5V @ 5 amps, +12V @ 1 amp, −5V @ 1 amp, −12V @ 1 amp

APS-2 $109.00
Switching Power Supply for APPLE II; +5V @ 3 amps, +12V @ 2 amps, −5V @ ½ amp, −12V @ ½ amp; c/w on-off switch & connecting wires

AAA-2
Disc Drive, 5¼", APPLE II Compatible, Excluding Controller Card $395.00
with controller $450.00

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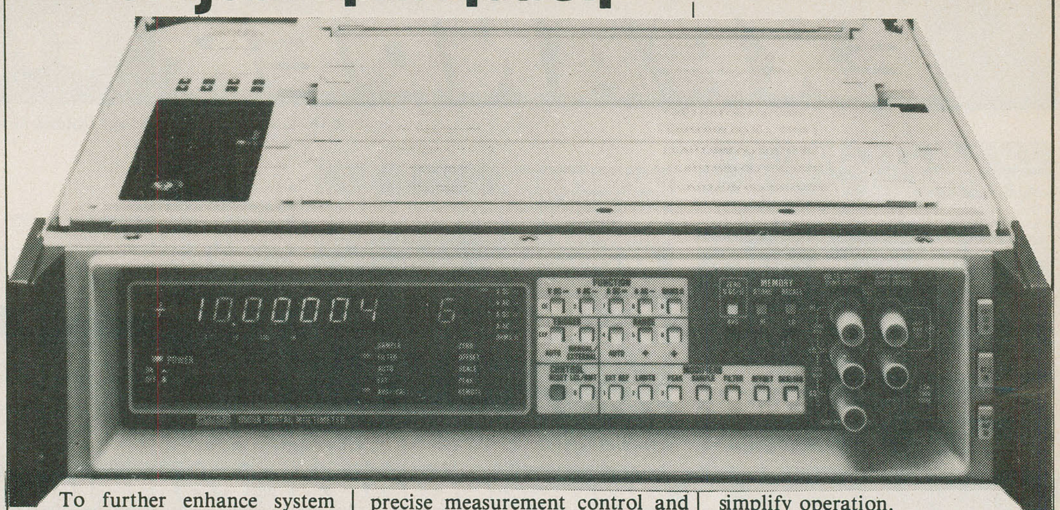
Modular Digital Multimeter



A new systems digital multimeter (DMM) featuring a combination of accuracy, speed and measurement capability has been introduced by John Fluke Mfg. and is available in Canada exclusively from Allan Crawford Associates Ltd.

The new Fluke model 8505A will measure DC volts at 10 ppm absolute accuracy (90 days, 18_C to 23_C). On the 10V DC range, the meter increases its resolution to 7½-digits. Up to 500 readings per second are possible in the DC volts mode at 6½-digit resolution and full accuracy. This is unequalled by any other DMM available today.

The instrument is modular in design so options can be added at any time for averaging or rms AC voltage measurements, as well as precision ohms and current. Interface options include full talk-listen IEEE-488, RS-232-C and several parallel configurations, offering a control solution appropriate for most system applications.

To further enhance system operation, the 8505A has switchable front-rear inputs. The position of the inputs may be sensed from the remote interfaces. It also features and external trigger input and a scanner advance output for precise measurement control and fast throughput.

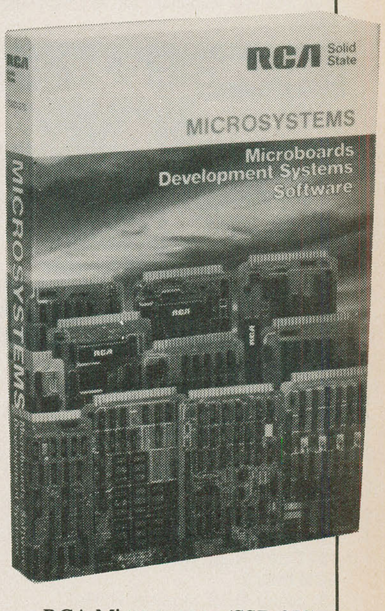
The 8505A is microprocessor based, providing a variety of internal math programs to enhance testing procedures. Prompting messages and error codes help simplify operation.

Contact: Mrs. Debbie Muraca, Allan Crawford Associates Ltd., 6503 Northam Drive, Mississauga, Ontario. L4V 1J2 (416) 678-1500.

New Microboard Databook

Complete technical information on the full line of the RCA Solid State Division's Microboard computer systems and microprocessor development systems is contained in the databook, "RCA Microsystems" (SSD-270).

Three separate sections provide ratings, performance specifications and user information for the CDP18S600 series of Microboard computer systems, the CDP18S family of microprocessor development systems and the software required to operate both.



RCA Microsystems (SSD-270) is available for $7.00 U.S., payable by check or money order from the RCA Solid State Division, Box 3200, Sommerville, N.J. 08876. The databook is also available from RCA sales offices and authorized distributors.

Also...

Northern Telecom of Canada today announced that its SL-1 digital business communication system has been granted type approval by Nippon Telegraph and Telephone Public Corporation (NTT), the Japanese government telecommunications authority. With type approval, the SL-1 systems may now be used in the Japanese public telephone system.

In addition to the SL-1, type approval was also granted for the SL-1 electronic telephone set and for Northern Telecom's Add-on Data Module, which permits data communications as well as voice to be switched through the SL-1.

Northern Telecom and Mitsui & Co., Ltd. of Japan have signed a long-term agreement under which Mitsui will distribute the SL-1 in Japan. With the granting of type approval, Mitsui will now begin an active marketing program to sell SL-1 systems to Japanese customers, directly and through sub-distributors.

Northern Telecom is the largest manufacturer of fully digital switching and transmission systems in the world. To date, North Telecom has nearly 6,000 SL-1 systems sold or on order, to serve about 2.3 million telephone lines in 40 countries around the world.

•

With U.K. sales running at 50,000 units per month, Britain's fastest-selling home computer, the Sinclair ZX Spectrum, is to be launched in over 30 countries worldwide.

"We anticipate initial sales of 15,000 per month rising sharply through the remainder of the year," commented Sinclair's managing director, Nigel Searle, "and plan to increase Spectrum production significantly to meet overseas demand."

While it is concentrating at first on European markets, Sinclair Research has also received large advance orders from its agents in South American and the Far East, and is strengthening its export team to open up new markets in the Middle East and the Third World. There is still no word on North American availability.

•

European micro-computer market leaders Commodore Business Machines (UK) has announced a $50 million program to build personal computers in the English midlands.

The new manufacturing facility is expected to employ over 300 people by the end of next year, and will become the company's manufacturing and distribution centre for Europe.

•

Job vacancies for engineers, accountants, executives and other professionals increased 13% in the last three months, according to the Technical Service Council/Le Conseil de Placement Professionnel, a non-profit placement service run by industry. The increase was the first in 21 months and follows the longest decline since the survey started in 1969. However, vacancies decreased 66% in the last 12 months. TSC's quarterly survey is based on job listing by 1,700 mining, manufacturing, construction, consulting and service organizations. It does not represent openings in governments or in institutions. Ontario reported the largest number of openings (293), down 72% from a year ago. Alberta was the second with 158 and 70%, followed by B.C. (116 and 28%) and Quebec (90 and 59%). The number of openings in other provinces was so small that percentage changes are not significant.

"Employers are more optimistic about the economy than they were three months ago," according to Neil A. MacDougall, president of Technical Service Council. "However, the recent increase in hiring has been sporadic. It's not yet certain that a sustained upturn in employment has started."

•

According to Public Affairs International in co-operation with the Electronic Equipment Manufacturers Association, Mr. Donald Johnston, Minister of State for Science and Technology, has received general approval of his technology policy paper. The emphasis in the paper is expected to be on the application of new technology within industry, both to boost technology-intensive jobs and to increase productivity. It is also anticipated that there will be efforts to increase the number of firms doing R & D, hopefully raising the R & D target to 2% of the GNP by 1990 and to recommend additional incentive spending of about $300 million for 3 to 5 years. The timing of further development is uncertain at the moment due to linkage to the budget and/or the Speech From the Throne.

•

Edukits, the Toronto-based electronic kit manufacturers, have completely revised all their kits and instructions resulting in a very much improved range. ETI has seen examples of these and we are impressed; everything seems to have been thought of. According to Mke Doyle of Edukits, the new kits are selling very well, principally in Ontario but soon the rest of Canada will be well served. The latest addition to the range is 0-24V, 0-1A regulated power supply retailing for $49.95.

Edukits, P.O. Box 38, Station 'N., Toronto, Ontario. M8V 3S4.

Test Leads

Leads in Coline's TLS 2000 series carry a safety certificate from UL and are rated at 1 kV, 10 A. The set comprises two 1.5 m long, silicone rubber-insulated leads with a shrouded 4 mm plug at each end. Pairs of probes, spring hooks, spade terminals and alligator clips are also included. Items can be purchased separately. Contact BCS Electronics, 980 Alness St., Unit 7, Downsview, Ont. M3J 2S2, (416) 661-5585.

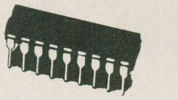
Correction:

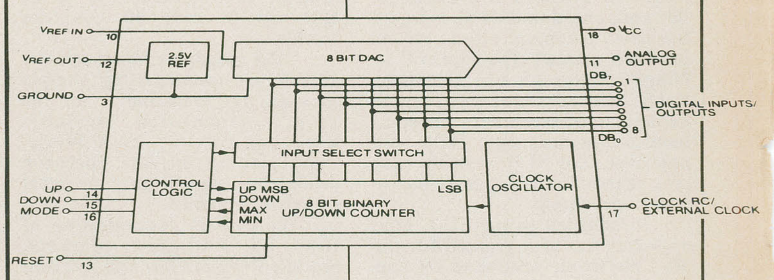
In the May Digital Capacitance Meter, potentiometer PR2 is shown incorrectly in the Parts List as 47K ohms. This should have been 4K7. The schematic is correct in this respect.

Multiple-Use Data Converter

Now available from Ferranti Semiconductors is a new 8-bit multifunction data converter. Designated ZN435, this monolithic IC is composed of a voltage output DAC, on-chip precision reference, 8-bit binary up/down counter, 8-bit I/O port, clock oscillator, input select switches and control logic.

Extremely versatile, the ZN435 can be configured to operate in a variety of modes, such as DAC, ADC, tracking ADC, voltage-to-frequency converter, wave form generator, track-and-hold circuit, and voltage-controlled oscillator. Additional features include 8-bit accuracy, 800 ns settling time and single +5V supply operation.





The ZN435 is currently available in an 18-pin plastic DIP (ZN435E) for 0__C to +70__C operation and an 18-pin ceramic DIP (ZN435J) for -55__C to +125__C operation. The ZN435E is priced at $4.95 U.S. in quantities of 100.

For technical specifications, write or call Ferranti Semiconductors, 87 Modular Avenue, Commack, NY 11725, (516) 543-0200.

Terrestrial Interference

The RF spectrum must be getting to look like a bargain basement during a 99¢ sale. The trick is to prevent various signals from getting in the way of yours, and a publication is offered which is said to aid you in setting up various suppression/avoidance techniques. It should be particularly useful to those with satellite receivers in RFI-prone locations. It's called ASTI, for Avoidance/Suppression of Terrestrial Interference and is available (before July 1) for $99 U.S., from Howard Shippey, Microwave Filter Co. Inc., 6743 Kinne Street, East Syracuse, N.Y. 13057, (315) 437-3953 collect. No mention is made, presumably, of what you do for extra-terrestrial interference.

Polyphonic Organ

PROJECT

Featuring a 'touch sensor' keyboard constructed right on the printed circuit board, this polyphonic organ project covers a two-octave range, has loudspeaker output plus two 'voices' and can be operated from a battery or AC adapter.

**by Barry Wilkinson
Roger Harrison**

TWO PROBLEMS come to mind when you consider small organs and synthesizers. One is the fact that they may only play three notes at once, and the other is the size and expense of the keyboard. The ETI electronic organ solves both problems: it's polyphonic, which means any number of notes can be played simultaneously, and the keyboard is incorporated into the printed circuit tracks.

Many notes

There are two basic ways to generate many notes than can be sounded simultaneously. You can commence with a 'master' oscillator at some suitably high frequency and have a series of frequency dividers that divide this down stage by stage to produce the required range of notes. This has the advantage that only a single tuning control is required to set all the notes on frequency. That's fine and dandy, but the pitch interval between notes in the chromatic scale (i.e. the ratio of a note to the note above or below) is based on the twelfth root of two. This means that, to produce a scale based around middle C, at least, the lowest frequency you can start off with is around 2 mHz. A string of dividers constructed from discrete ICs would consist of many devices and be quite expensive. However, there is a device called a 'top octave synthesizer' which performs this task — but further dividers are required to produce the 'usual' range of notes. The drawback is the cost — the crystal and top octave synthesizer will set you back around $30 to start with!

For cost reasons, we've chosen the second method. Twenty-five oscillators have been used to generate each of the notes in a two octave-plus-one range from F below middle C to F'' above middle C.

Each oscillator is implemented using a single two-input gate — and that includes the touch sensor keying! Hence all the oscillators require only seven quad-gate ICs — leaving two space gates which have been used in the tremolo circuitry. In addition, Schmitt-input CMOS gates have been employed (4093s) as they have two distinct threshold points on the inputs which means they can be driven on or off with certainty, unlike conventional CMOS gates, such as 4011s which have only one threshold point. Using this, the problem with moisture on the keyboard holding notes on has been largely overcome. The action of each oscillator and how they are keyed is explained in detail in the *How It Works* panel.

This project has tremolo circuitry and two 'voices', but the circuitry has been arranged differently this time.

Loudspeaker output is provided by an LM380 audio power output amplifier IC. This is capable of driving 1 W into a four ohm load from a 9 V supply and for this reason we have specified the use of two small speakers. The common 50-75 mm diameter loudspeakers generally have an eight ohm voice coil. Connecting two in parallel gives a four ohm load and considerably more output. You can add a jack socket to take the organ's output to an external amplifier if you wish, in which case you'll get a much richer sound.

Construction

For clearly obvious reasons, you'll get best results using our pc board design. However, if you intend making your own pc board, we should point out that tarnishing of the copper on the keyboard area can be a problem. We solved that on the prototype by coating it with solder. It's a fair solution, but not all that pretty!

Make a careful check of the pc board before commencing construction. Check that all the holes are drilled to the correct size. This is particularly important with the row of trimpots. You may need to drill holes near the two ends of the board, above the keyboard area, so that mounting pillars can be screwed to the board. Exactly where and what size will depend on how you're going to mount the board, and that we'll have to leave up to you. Some suggestions are given later. Check that the two slide switches fit in the slots in the pc board. Enlarge the slots with a small file if necessary.

Having satisfied yourself that the board's all OK, all the trimpots can be fitted first. All the resistors can be soldered in place next, mounting them right down on the pc board.

The LM380, IC9, should be soldered in place next. Make sure you orient it correctly. Now cut two 'flag' heatsinks, as shown in the accompanying illustration. You can use tinplate or thin copper 'shim'. Both can be obtained in small sheets from hardware stores. Arts and craft stores have sheet stock used in copper tooling. Tin the two tags at the bottom, each on the side that solders to the LM380 pins. You'll need an iron capable of supplying quite a bit of heat and having a 'chisel' bit. Don't overdo the solder. Then, carefully tin pins 3-4-5 and 10-11-12 on the LM380. Take one of the flags and orient it as shown in the diagram. Hold the tag with the solder side against the appropriate pins of the LM380 using a pair of pliers. Apply the flat of the iron to the tag until you see the solder flows freely. Remove the iron and *keep the flag steady until the solder sets.* This process is known as 'sweating'. If you hold the flag with your fingers while doing this you'll know

exactly what it means! Now sweat the other flag to the other set of pins of the LM380. Do this carefully. While the LM380 is quite rugged, don't overdo it with the soldering iron. If you make a slip and have to resolder it, let it all cool down first.

If you plan on using the organ with a hifi or instrument amplifier, you can eliminate the LM380 and speakers entirely. The line output can be taken from the slider of RV9, the volume control (Point B on the schematic). If the output level isn't adequate, you can increase the gain by shorting R43, the 47K attenuator resistor. Use any suitable audio connector with its common or shield terminal connected to the "0 V" point on the circuit board.

Having accomplished that task, insert all the other ICs and solder them in place, making sure — as always — you have them correctly oriented. ICs 1 to 7 are CMOS types. Use either an isolated soldering iron or an iron with a grounded tip. Handle the ICs by their ends, avoiding touching the pins. Solder the supply pins (7 and 14) first.

Now come the capacitors. The only thing you have to watch for here is the polarity of the electrolytics and tantalums.

It's probably a good idea at this stage to have a quick check over what you've done so far.

Now attach all the leads that run from the pc board to the two potentiometers, the two switches and the speaker(s). The three wires adjacent to C12 that run to the volume pot RV9 should be tinned copper wire. It makes life easier in a moment.

Now mount the two potentiometers, RV9 and RV27, and wire them up. Follow with SW1 and SW2. We glued our switches in place with quick-setting epoxy, but they could be screwed to the board. Attach the speaker(s) and the battery clip. Put knobs on the two potentiometer shafts.

Resist the urge to plug in a battery and try it out (it'll be out of tune anyway). First, *check everything.* Check the IC orientations especially. All OK? Now you're ready for the next bit.

First try out

Set the VOICE switch to 2. DEPTH control fully anticlockwise (minimum) and the volume control about one-quarter advanced. Set all the trimpots to half travel. Switch on and touch one of the note keys. You should get a sound in the speaker. If not, try several other keys up and down the keyboard. Try VOICE 2 if you still get no response. If nothing happens there either, switch off and check connections and component orientations again. Correct any faults and try again. If you still have problems, check the voltage across pins 2 and 14 (+ve) of IC9 and pins 11 and 4 (+ve) of IC8. There should be 9 V or so on each. Also check that there's about 5 V across ZD1. With the TREMOLO off, check the voltage between the 0 V rail and pin 11 of IC8. There should be 5 V there. Then check the voltage between pins 1 and 14 (+ve) of ICs 1 to 7. There should be 5 V on each IC.

If all this checks out OK, you're going to have to do a bit of signal tracing. All this needs is a high impedance crystal earpiece, and a 100n capacitor in series with one lead. With one lead on the 0 V rail, put the other lead on pin 2 of IC8 and

HOW IT WORKS

A total of 25 separate oscillators are used to provide polyphonic output covering two octaves. Each oscillator is individually adjustable so that they can be accurately tuned to the required note. Apart from the set of note oscillators, there are three other sections to the circuitry: the tremolo circuitry, the voice selection/mixing and the audio output stage.

The Note Oscillators

All the note oscillators have identical circuitry; only the frequency determining components are varied to provide the individual frequencies for the notes. The note oscillators are based on one gate from a 4093 CMOS two-input Schmitt trigger NAND gate. The basic circuit is shown in Figure 1.

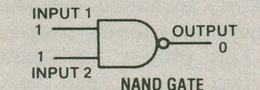
The one gate combines both an oscillator and the keying action. What makes the gate oscillate is the feedback loop from the gate output to Input 2 via the trimpot and resistor in series and involving the capacitor C.

A NAND gate is a digital IC and it operates according to certain 'rules', spelled out in a 'truth table'. Voltage levels on the gate's inputs or output are either 'high' or '1', which means they're at the positive supply voltage, or they're 'low' or '0', which means they are at the 0 V rail. With a two-input AND gate, the output will be high if Input 1 AND Input 2 are high, otherwise the output is low. Hence the name, AND. The NAND gate is a NOT AND gate which simply means that its output is inverted to that of the AND gate. Thus, if Input 1 and Input 2 are both high, the output will be low, not high. The truth table for a NAND gate is given in Table 1.

While we said that a '1' or high normally means the supply voltage and '0' or

TABLE 1.

Input A	Input B	Output
'0' (low)	'0' (low)	'1' (high)
'1' (high)	'0' (low)	'1' (high)
'0' (low)	'1' (high)	'1' (high)
'1' (high)	'1' (high)	'0' (low)



NAND GATE
INPUT 1(1) NOT AND INPUT 2(1) = OUTPUT (0)

AND GATE
INPUT 1(1) AND INPUT 2(1) = OUTPUT (1)

While we said that a '1' or high normally means the supply voltage and '0' or low the 0 V rail, the inputs of a NAND gate are generally

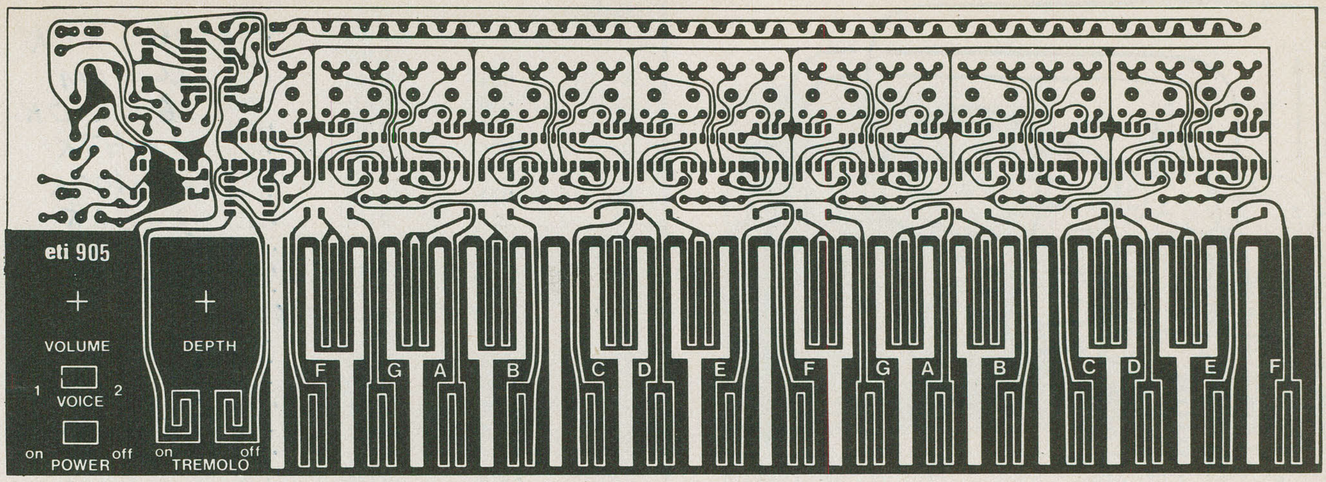
low the 0 V rail, the inputs of a NAND gate are generally specified to operate for voltages between these extremes. With a normal CMOS gate there is an input level threshold of about 50%. This means that if the input is at a level above 50% of the supply voltage it is low. The actual percentage (threshold) can vary from device to device (the limits are 30% to 70%). However, there is a point above which it is definitely high and a point below which it is definitely low. This is the *normal* input characteristic of CMOS gates. They only have one threshold point.

With a gate having Schmitt inputs, there are two distinct thresholds: there is a low threshold which, if the input level is below that limit, the input is low and there is a high threshold which, if the input level is above that limit, the input is high. Between the two thresholds, the inputs do nothing. The low threshold may be at 40% of the supply rail, the high threshold at 60% of the supply rail.

Referring to Figure 1, in order to this circuit to oscillate, Input 1 must be driven high. Initially, it will be held low by the 1M resistor. If you look at the truth table, if either input is low, the output must remain high. Input 1 is taken high by the action of placing a finger across the key pads. Just before Input 1 goes high, the output of the gate must be high and, owing to the trimpot RV and the resisitor R, Input 2 will also be high and capacitor C will be charged. Thus, when Input 1 goes high the output will immediately go low as both inputs will then be high. Input 2, however, now starts to go low due to the feedback via RV-R, but this action is slowed down by the capacitor having to discharge via RV-R. When the voltage on Input 2 reaches the low threshold, the output will suddenly go high. Thus, C will begin to charge again via RV-R. When Input 2 reaches the high threshold, the output will revert to the low condition once more and the whole cycle will be repeated.

This continues with the output going high/ low/high at a rate largely determined by the RC network formed by RV, R and C. (The difference between the low and high thresholds, the hysteresis, affects it too). By varying the resistance of the trimpot RV, the frequency of the note oscillator can be varied. The circuit will oscillate so long as Input 1 is held high by placing a finger on the key pad.

Note that each oscillator has been given a frequency variation range of 2:1 because of the values assigned to RV and R in each oscillator. The major frequency determining component in the actual circuit is thus the capacitor (C). Only standard value (E12 series) components have been



Because of the size of the keyboard printed circuit, we are including a 50% reduction. This can be expanded by printed circuit manufacturers to its full length of 34.5 cm. However, if you would like a full size copy, we will mail it at no charge if you send a 300 x 250 mm stamped, self-addressed envelope to:
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touch one of the keys. You should get a sound. Try several other keys, or all of them, to see that you get a sound from each group of oscillators. If not, then check the circuitry around ICs 1 to 7. If the oscillators work, check that you're also getting signal across the two outer terminals of the volume control, RV9. If not, the fault is probably in the wiring of SW2 or IC8 is faulty. If you do get signal there, check with the earpiece that you're getting signal at pin 6 of the LM380. If not, RV9 wiring is probably faulty. If signal's there, check to see that it may be on pin 8 of the LM380. If so, then the

specified so that components are easy to obtain and inexpensive as these are the most common values available.

Voice Selection, Mixing

The output waveform of the oscillator described is a square wave, as you would no doubt have already realised. The output signals from each of the 25 oscillators are mixed together via a resistor network to the inputs of IC8/1 and IC8/2, two op-amps from an LM324 quad op-amp package. Apart from performing the mixing, this stage provides the 'voicing' as well. IC8/1 has a capacitor (C11) across the feedback resistor (R41) which changes the waveshape into a triangular form. This removes most of the harsh odd-order harmonics of the square wave, producing a 'sweeter' sound. As this type of circuit is frequency dependent, the mixing resistors from the oscillator output have different values so as to keep the amplitude constant across the frequency range. The desired voice is selected by switching between the outputs of IC8/1 and IC8/2 using SW2.

Audio Output Stage

Final amplification of the signal, to drive a loudspeaker, is done by an LM380 IC

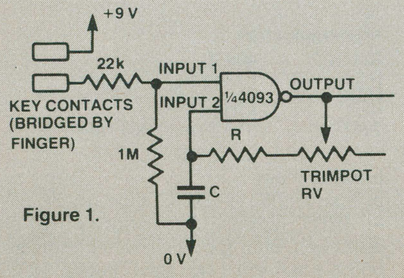


Figure 1.

power output amplifier (IC9). This can drive low impedance speakers and will deliver over one watt into a four ohm load. One or two miniature 8 ohm loudspeakers can be used for audio output. We used two 8 ohm speakers in parallel to give four ohms so that the LM380 will deliver maximum output. However, the output can be coupled to an external loudspeaker mounted in a proper enclosure (i.e. a hi-fi speaker), better sound being obtained in this way. The larger speakers are generally more efficient, which is opposite to what most people first think, and the LM380 generally clips when several notes are played together while driving the very inefficient miniature loudspeaker(s).

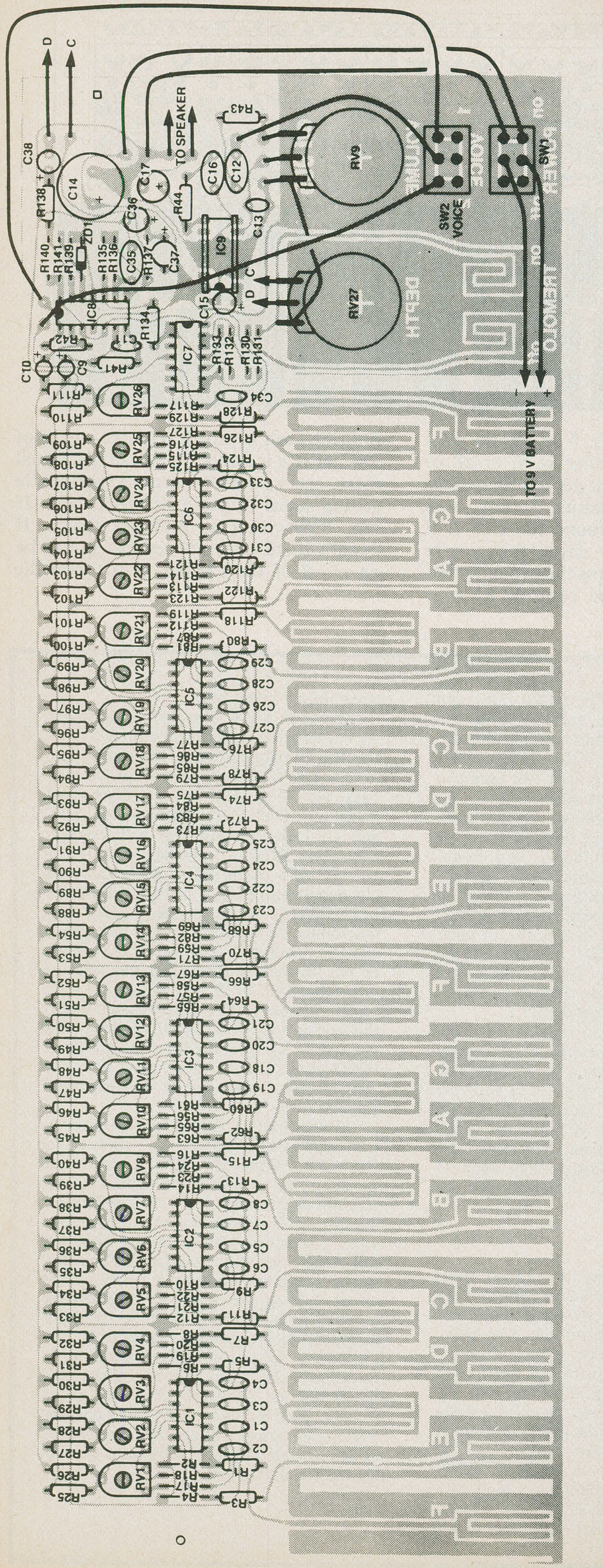
Capacitor C12 and resistor R43 provide some low frequency roll-off, reducing 'thump' when you touch a keypad. Volume control is provided by RV9. C13 rolls off the high frequencies, reducing the harshness of the sound. The RC network across the speaker outputs from IC9 (R44-C16) helps stabilise the LM380 at high frequencies. C17 provides dc isolation for the speaker.

Tremolo Circuitry

This part of the circuitry involves two gates from IC7 and the remaining two op-amps from IC8. Tremolo is started and stopped by touching the appropriate key pads. IC7/2 and IC7/3 are arranged as a RESET/SET(R/S) flip-flop. If pins 12-13 of IC7/3 are high, pin 11 will be low and thus pin 8-9 will be low, pulled down via R133. This is the 'tremolo off' condition. If pins 8-9 of IC7/2 are pulled high by touching the ON key pad, pin 10 of IC7/2, which would have initially been high, will go low, as will pins 12-13 of IC7/3. Thus, pin 11 of IC7/3 will go high. This is the 'tremolo on' condition.

Now, IC8/3 is arranged as a low frequency oscillator. When pin 10 of IC8/3, the non-inverting input, is low, pin 8 is held low, and so will pin 9 because of the feedback via R136. C35 will be discharged. When pin 10 of IC8/3 is driven high, pin 8 will go high too and C35 will begin to charge via R136. The voltage on pin 9 of IC8/3, the inverting input, will begin to rise at a rate determined by the RC combination of C35-R136. As the voltage on pin 9 rises, the voltage on the output of IC8/3, pin 8, will begin to fall — and so will the voltage on pin 10, the non-inverting input, because of feedback via R135. At a certain level, the op-amp output will be rapidly driven low by the feedback action, C35 will discharge and the whole cycle will start again. Thus, IC8/3 oscillates. It will do so at a rate of about 10 Hz, determined by the component values chosen.

The output is filtered to more or less a triangular shape by the RC network of R137-C36. Capacitor C37 provides dc blocking, the output being applied to the tremolo depth control, RV27. The signal is applied to the inverting input of IC8/4 which is a dc amplifier stage. The output of this stage is set to an average of about 5 V as the non-inverting input is 'clamped' at about 5 V by the zener ZD1. When the modulating signal from the 10 Hz oscillator is applied to the inverting input of IC8/4, the output voltage will swing about a 5V mean, modulating the supply voltage to all the oscillators. The amplitude of the swing is determined by the tremolo depth control. Varying the supply voltage to the oscillators causes a small frequency variation, producing the tremolo effect.



PARTS LIST

Resistors

R1		22k
R2		1M
R3		22k
R4		1M
R5		22k
R6		1M
R7		22k
R8		1M
R9		22k
R10		1M
R11		22k
R12		1M
R13		22k
R14		1M
R15		22k
R16		1M
R17-24	7	220k
R25		47k
R26		100k
R27		56k
R28		100k
R29		56k
R30		100k
R31		56k
R32		100k
R33		68k
R34		100k
R35		68k
R36		100k
R37		68k
R38		100k
R39		82k
R40		100k
R41		47k
R42		10k
R43		47k
R44		2R7
R45		82k
R46		100k
R47		82k
R48		100k
R49-54	6	100k
R55-59	5	220k
R60		22k
R61		1M
R62		22k
R63		1M
R64		22k
R65		1M
R66		22k
R67		1M
R68		22k
R69		1M
R70		22k
R71		1M
R72		22k
R73		1M
R74		22k
R75		1M
R76		22k
R77		1M
R78		22k
R79		1M
R80		22k
R81		1M
R82-87	6	220k
R88-89	2	100k
R90		120k
R91		100k
R92		120k
R93		100k
R94		120k
R95		100k
R96		150k
R97		100k
R98		150k
R99		100k
R100		150k
R101		100k
R102		180k
R103		100k
R104		180k
R105		100k
R106		180k
R107		100k
R108		220k
R109		100k
R110		220k
R111		100k
R112-117	6	220k
R118		22k
R119		1M
R120		22k
R121		1M
R122		22k
R123		1M
R124		22k
R125		1M
R126		22k
R127		1M
R128		22k
R129		1M
R130-131	2	100k
R132-133	2	4M7
R134-135	2	100k
R136		1M
R137		10k
R138		100k
R139		39k
R140		10k
R141		100R

26 - 22K
26 - 1M
28 - 220K
3 - 47K
35 - 100K
3 - 56K
3 - 68K
3 - 82K
3 - 10K
1 - 2R7
3 - 120K
3 - 150K
3 - 180K
1 - 39K

RV 1-8,10-26	220k miniature trimpot, horizontal mounting such as Philips 410 series.
RV9	22k log. pot. (or 20k)
RV27	47k lin. pot. (or 50k)

Capacitors

C1-3	6n8
C4-6	8n2
C7,8,18	10n
C9-10	1u/16 V tant.
C11	33n
C12	100n
C13	330p ceramic
C14	1000u/16 V electro.
C15	10u/16 V electro.
C16	100n
C17	100u/16 V electro.
C19-21	12n
C22-25	15n
C26-29	18n
C30-33	22n
C34	27n
C35	100n
C36-38	10u/16 V electro.

Semiconductors

IC1-IC7	4093B
IC8	LM324N, uA324PC
IC9	LM380N
ZD1	5V1 zener, 400 mW

Miscellaneous

pc board; SW1 — DPST slide switch; SW2 — SPDT slide switch; one or two 50 mm diameter 8 ohm speakers; battery holder to take 6 x AA cells; two small knobs; 30 x 30 mm square of tinplate or copper shim; hookup wire; case, etc.

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Career opportunities.
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Track record with employers.
How do companies view the school you're considering?

—Do major corporations regularly recruit on campus?

—What percentage of graduates quickly obtain jobs in the field for which they are trained?

—What's the average starting salary?

Curriculum and Accreditation.
Does the school offer you a choice of programs in either Electronics or Computer Programming?
How long will it take to complete each?

—Is industry input a factor in developing and updating programs?

—Does coursework also include communications, economics and other generalized studies related to your technical training?

—Is the school accredited, and are its programs also recognized by professional organizations?

Instructors and Facilities.
Student aid, campus activities.
Do instructors have relevant industry experience along with their educational credentials?

—Is state-of-the-art equipment provided for hands-on training?

—Does the campus include a comprehensive library?

—Does the school have an active, ongoing program to help students obtain financial aid, find housing and part-time jobs?

—Are there student organizations, and extracurricular activities in which you can participate?

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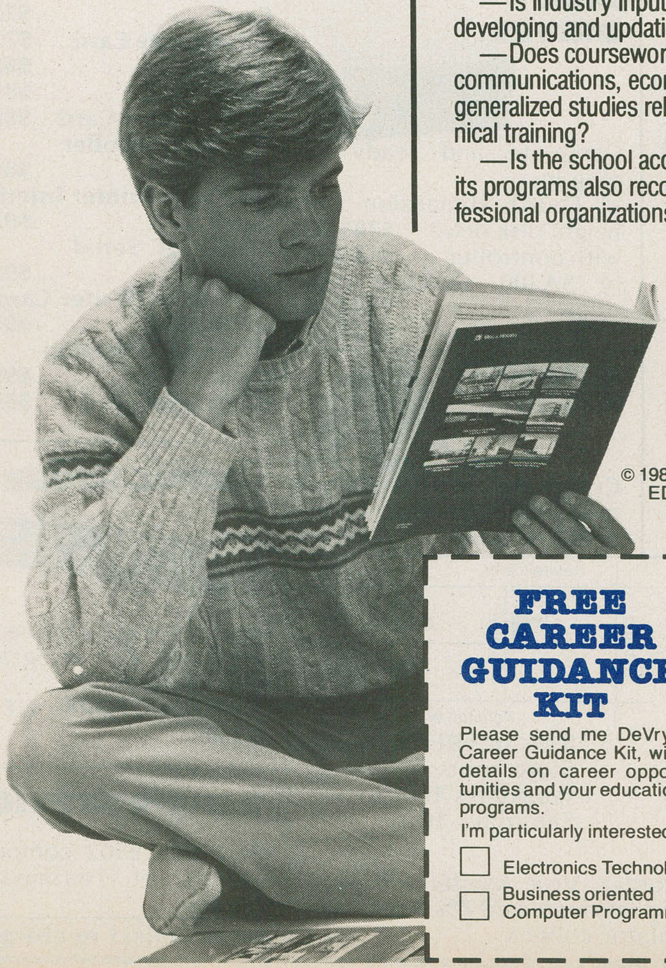

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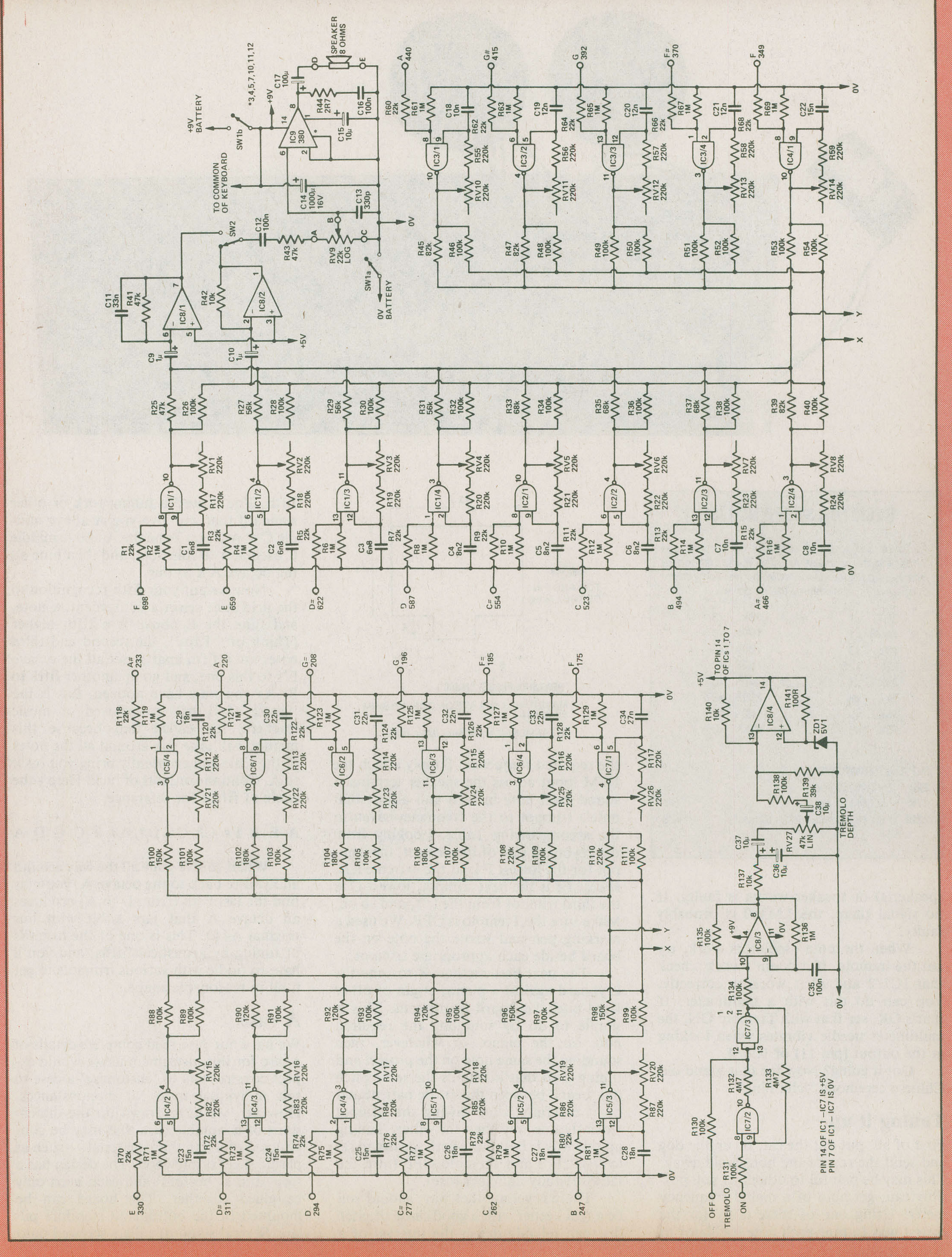
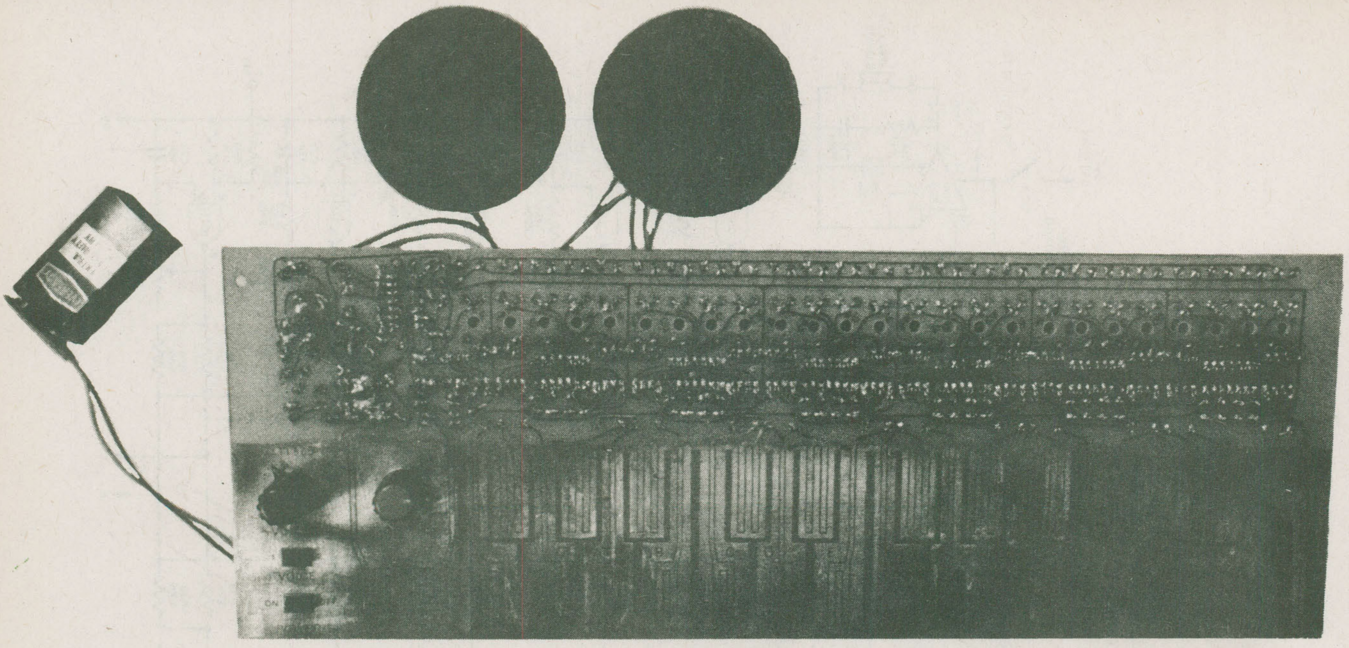




RESISTOR SHOPPING LIST

As there are so many resistors used, here is a 'shopping list' to assist you. The Parts List can be referred to in conjunction with the component overlay when assembling the pc board.

2R7	x1	82k	x3
100R	x1	100k	x34
10k	x3	120k	x3
22k	x25	150k	x3
39k	x1	180k	x3
7k	x3	220k	x27
56k	x3	1M	x26
68k	x3	4M7	x2

POTS & TRIMPOTS

22k	(or 20k) log pot.	x1
47k	(or 50k) lin pot.	x1
220k	min. horizontal mount trimpots	x25

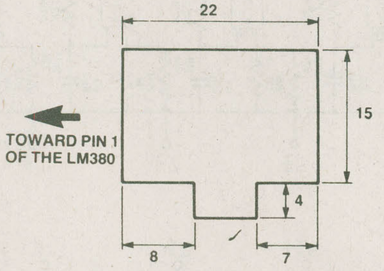
speaker(s) or speaker wiring is faulty. If no signal there, the LM380 is probably faulty.

When the note oscillators work, try out the tremolo. If it doesn't work, check that IC7/2 and /3 is working correctly. You can do this with a multimeter. If that's OK, see that with Tremolo ON, the multimeter needle vibrates when looking at the output (pin 11) of IC8/4.

Got it going? Now for that grand old Chinese ceremony "chu ning".

Tuning it up

First of all, put out the cat, tie up the dog and send the rest of the household away. This may be painful to others. If you possibly can, get hold of a digital frequency meter. Using one of these is by far the easiest way to tune each note oscillator to



HEATSINK FLAGS, LM380

MATERIAL: TINPLATE OR COPPER SHIM
TWO OFF

ALL DIMENSIONS IN MILLIMETRES

the required frequency. Simply attach the DFM input across the speaker terminals, sound each note in turn and adjust that note's trimpot to the frequency given in the accompanying Table. Looking from the keyboard side of the project, the trimpot for the lowest F is at the extreme left, lowest F# is the next trimpot, lowest G is the third trimpot from the left, and so on. Make sure the Tremolo is OFF. We used a marking pen and wrote the note on the board beside each appropriate trimpot.

The next best method is to tune the keyboard against a piano, organ or other fixed-pitch keyboard instrument. This is simple to do by sounding the required note on the piano, or whatever, then sounding the same note on the project and tuning it so that it sounds the same pitch (no 'beats' between them). Be patient and do it carefully, don't swing the trimpot violently one way then the other. Tuning up this way is best done with the organ set to VOICE 2 and Tremolo OFF (turn the DEPTH fully anticlockwise).

There is yet another way, should you be a real keener with a good sense of pitch that can reliably detect the interval of a fifth. You'll need a tuning fork or other standard that will give you A above middle C at 440 Hz. Tune the A above middle C oscillator to this note, and then tune all the octave A's to this.

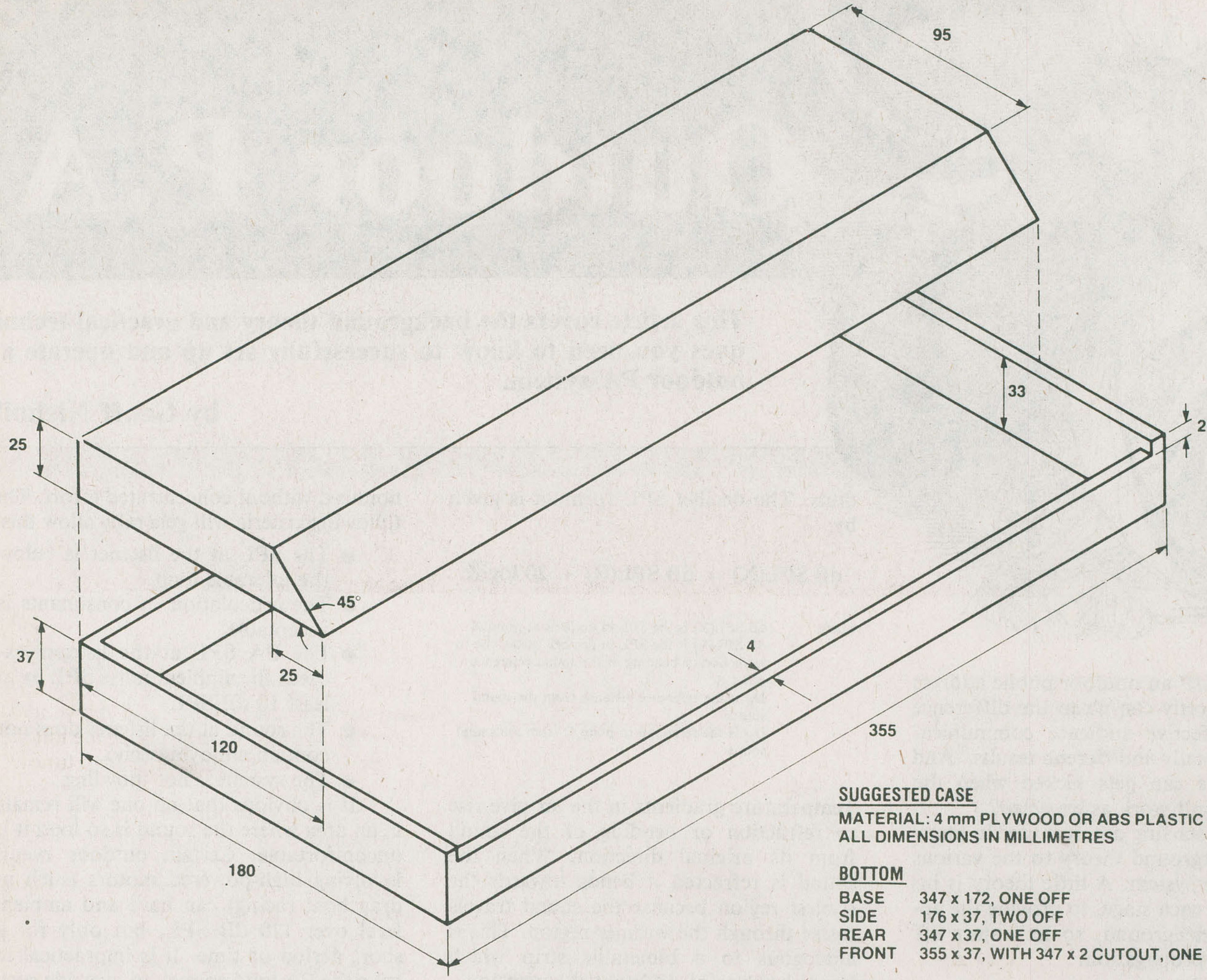
Now we put your fifth-recognition to the acid test: select a convenient A note, and tune the E above it a fifth higher (Think of "Taps"; the second and third notes are a fifth apart). Set all the octave E's to this one, and go up another fifth to B. As you may have noticed, this is the "circle of fifths" so beloved of music teachers; it's called that because this method will take you around all the notes of the scale and eventually bring you back to A. Continue on; lots of luck. Here's the circle of fifths for reference:

A E B F# C# G# D# A# F C G D A

When you've gone all the way around and you're back to the octave A, you may find the last fifth (from D to A) produces an octave A that jars a bit with our original A440. This is one of the hazards of tuning by acoustical fifths, and you'll have to fiddle with various trimpots to get it all in reasonable shape.

A case

We have not described complete details of a case for this instrument as we would expect constructors to 'customise' a case to suit individual tastes or circumstances. However, we have drawn up the dimensions of a suitable case that may be constructed of 4 mm thick material — such as plastic sheet or plywood. The design has a 'top' and a 'bottom' and each need only be glued together. The board can be mounted in the bottom on standoff pillars. Several standoff pillars screwed onto



SUGGESTED CASE

MATERIAL: 4 mm PLYWOOD OR ABS PLASTIC SHEET
ALL DIMENSIONS IN MILLIMETRES

BOTTOM

BASE	347 x 172, ONE OFF
SIDE	176 x 37, TWO OFF
REAR	347 x 37, ONE OFF
FRONT	355 x 37, WITH 347 x 2 CUTOUT, ONE OFF

COVER

TOP	355 x 95, ONE OFF
SIDE	120 x 25, 25 x 45° CUTOUT, TWO OFF
FRONT	355 x 35, CHAMFERED EDGES, ONE OFF
REAR	347 x 21, ONE OFF

NOTE FREQUENCIES

F	698.5
E	659.3
D#	622.3
D	587.3
C#	554.4
C	523.3
B	493.9
A#	466.2
A	440.0
G#	415.3
G	392.0
F#	370.0
F	349.2
E	329.6
D#	311.1
D	293.7
C#	277.2
C	261.6 (middle C)
B	246.9
A#	233.1
A	220.0
G#	207.7
G	196.0
F#	185.0
F	174.6

PLAYING TIPS

The 'keys' should be played with the ball of the finger, not the tip. There is no "touch" to the instruments — hitting the key hard will not alter the sound in any way. This is much like a real organ. Touch the keys smoothly and firmly.

Under extremely humid conditions, or if you have greasy fingers, some trouble may be experienced with notes holding on. Wipe your hands thoroughly and the keyboard, too.

the board could then support the case top. The accompanying drawings show the rudimentary details. The completed case could be covered in self-adhesive vinyl, or something similar.

Batteries, supply

The project was designed to be powered by a 9 V battery or other sort of DC supply. It draws around 40 mA at average volume during playing, somewhat over 100 mA at full volume. You can use a No. 216 9 V (transistor radio) battery, but we recommend you get either an extra heavy duty type or an alkaline battery. Alternatively, you could use 6 x AA cells in a 'six pack' battery holder. You can dispense with the battery and use an appropriately rated adapter if you like. An adapter rated at 6 V/200 mA will deliver voltages around 8 - 9 V at current loads under 100 mA, and such an adapter would be the best to use if you want to power the project from the power line.

ETI

Outdoor P.A.

This article covers the background theory and practical techniques you need to know to successfully set up and operate an outdoor PA system.

by Geoff Nicholls

SETTING UP an outdoor public address system correctly can mean the difference between effective audience communication and totally indifferent results. And guess whose can gets kicked when the system doesn't work as expected?

Before starting out, it is wise to know a little background theory to the various parts of the system. A little theory is introduced at each stage, to provide the appropriate background, so let's start off with sound propagation.

Sound propagation

Sound propagates from a vibrating source in the form of longitudinal mechanical waves, which oscillate the particles in the medium along an axis in the direction of sound propagation.

The velocity of sound in still air is temperature dependent, and is approximated by the formula:

$$v = 20\sqrt{273 + T}$$

where v = velocity of propagation in m/s
T = air temperature in °C

Logic would suggest that the sound pressure level should fall off with increasing distance from the sound source by an inverse square law, because of the expanding area of the sound wavefront. In fact, additional losses are present due to dissipation of the sound energy by mechanisms too complex to discuss in this article.

These loss processes are frequency dependent, and lead to increasing attenuation of high frequencies with distance, but fortunately they can be ignored for speech frequencies up to distances of about 100 m. The inverse square law is therefore adequate for *general* outdoor PA calcuations. The decibel SPL formula is given by:

$$\text{dB SPL(X)} = \text{dB SPL(R)} + 20 \log \frac{D_R}{D_X}$$

where dB SPL(X) is the SPL in decibels at point X
dB SPL(R) is the SPL in decibels at the rise to refraction or bending of the sound reference point R
D_R is the reference distance from the sound source
D_X is the reference to point C from the sound source

Temperature gradients in the air give rise to refraction or bending of the sound from its original direction. When the sound is refracted it bends towards the coolest region because the sound travels faster through the warmer region. This is analogous to a bimetallic strip which bends because of differential expansion.

Most outdoor venues are warmest near the ground during the day, and so the sound tends to bend upwards. One notable exception is over a large water surface, which during the day tends to be cooler than the air, and so causes sound to bend down towards the surface. This can cause sound to carry long distances over water.

Windy conditions cause sound to be refracted because of gradients in wind speed in a similar manner to temperature gradients. In general, winds are slower near the ground, and this causes an upward bend when the sound is into the wind and a downward bend when the sound is with the wind. Transverse winds have little effect on refraction, although irregularities in all winds cause scattering of the sound.

The ground will reflect a certain amount of sound and absorb the rest. The reflected part can be utilized to reinforce the direct sound and increase the overall level by up to 3 dB, depending on the ground surface.

Setting up a PA

A PA system will be satisfactory if all the listeners can understand what is being announced without concentrated effort. The following criteria will generally allow this:

- The SPL at the listener is below the tolerable limit.
- The articulation of consonants is acceptable.
- The PA SPL at the listener exceeds the ambient noise SPL by at least 10 dB SPL.
- The sound at the listener does not contain annoying echo.
- The system is not 'howling'.

It is obvious that no one will remain in an area where the sound is so loud it is uncomfortable. Certain outdoor events involving high-powered motors (such as drag boat racing) can have and ambient level over 120 dB SPL, but only for a short period of time. It is impractical to have the PA loud enough to override such ambient levels.

The articulation of consonants depends primarily on the voice characteristic of the announcer. Successful announcers usually have good consonant articulation. It is possible to improve this factor by using a shaped filter response, such as a speech filter.

The public address system sound must obviously be perceived as louder than the ambient noise, or it will be drowned out. An increase of SPL by 10 dB subjectively sounds twice as loud, and for outdoor set-ups forms a good signal-to-noise ratio to aim for at the limit of the PA coverage area.

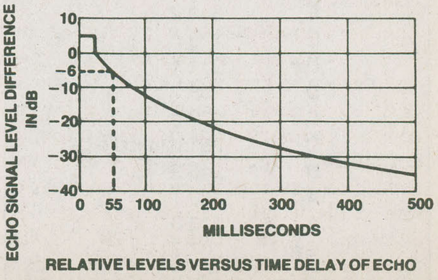


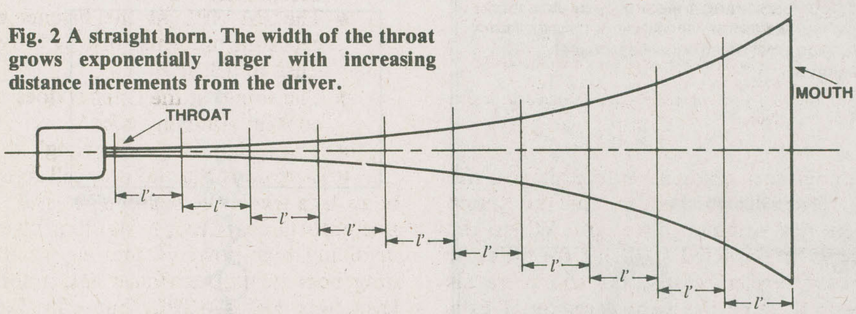
Fig. 1 Echo level versus time delay for 10% audience annoyance, produced by Doak and Bolt.

An echo will arise when there are unequal distances between the listener and two (or more) loudspeakers being driven by the same signal. An investigation by Doak and Bolt resulted in the compiling of a chart which allows us to estimate when an echo will become annoying to 10% of the audience. The chart plots the difference in SPL between the main signal and the echo against the time delay of the echo. An echo can also arise due to reflection off a hillside or building.

Acoustic feedback

Nearly everyone will have experienced the howling that occurs when a microphone is placed too near a loudspeaker it is driving. This phenomena is acoustic feedback and arises when the total gain of a sound system from the microphone through the amplifier to the speakers and back to the microphone exceeds unity. This usually occurs at a single frequency or a few dominant frequencies, because of peaks in the system response.

Fig. 2 A straight horn. The width of the throat grows exponentially larger with increasing distance increments from the driver.

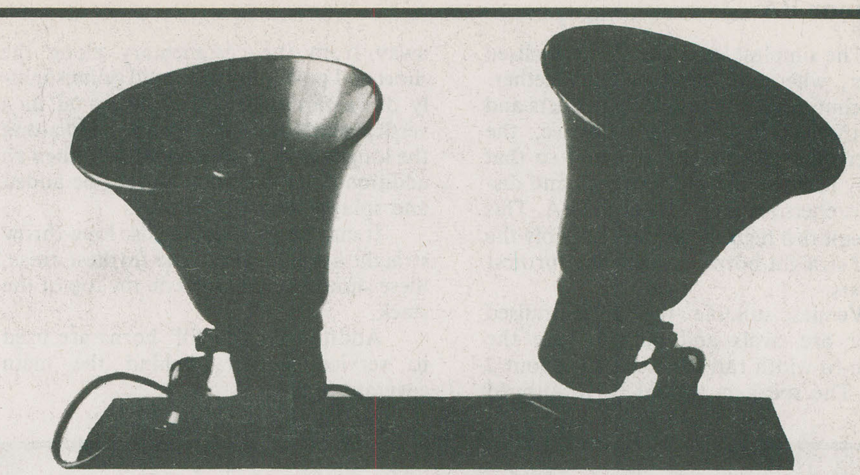


The problem of acoustic feedback is complicated when public address systems are used indoors because of the room shape which gives rise to many resonances. Complex equalisers are employed to smooth out the overall response and therefore allow the sound level to be increased before feedback occurs. Indoor public address techniques will be the subject of a future article in ETI.

Acoustic feedback is less of a problem in open spaces since there is usually only direct sound present — little or no reverberation from reflecting surfaces. Correct system layout should avoid feedback problems.

Speakers

The horn loudspeaker is by far the best type for outdoor use. Horns can be made weatherproof and have an efficiency of better than 20% compared to a few per cent for ordinary speakers. This allows an amplifier of lower power to be used, with consequent savings in electricity, physical size and weight. Horn speakers are available with inbuilt 100 V line transformers, usually with several taps to select different power levels. This allows some speakers to be placed closer to the audience and their output reduced to



compensate without affecting other speakers on the 100 V line.

Horns are intrinsically limited in their frequency response, and their efficiency is inversely proportional to their bandwidth. PA horns are designed to operate over the voice band at maximum efficiency. The horn itself is essentially an impedance transforming device which increases the acoustic loading on the driving diaphragm to allow better matching to the air. The shape of the horn is usually based on the exponential function and provides a cross sectional area which is dependent on distance along the horn by the formula:

$$A = A_O E^{MX}$$

where A = area of cross-section at distance 'x' from throat
A_O = throat area
E = Naperian base (2.718128)
m = 'flaring' constant.

The horn may be straight, as shown in Figure 2, or folded, as shown in Figure 3. The folded horn is physically smaller and is the most common type in low cost PA systems. Folding the horn reduces the efficiency slightly but increases the coverage or dispersion, which is usually an advantage. The straight horn has a long 'throw' and is useful for narrow sound coverage at greater distances but is more cumbersome, especially when you are 8 m up a ladder!

Microphones

A good microphone forms the heart of a good PA system and vice versa. The most suitable type for outdoor use is the unidirectional, low impedance dynamic microphone. This type is rugged and can withstand the abuse an outdoor setup will inflict. The directional characteristic is extremely important when the announcer is within the range of the speakers, and can make a big difference to the sound level attainable before feedback occurs. The low impedance microphone can also be used with a longer cable than the high impedance types, and will not pick up as much interference.

System layout

The overall performance of an outdoor PA is dependent on the location and type of loudspeakers and microphones. The placement of the amplifier and microphone is usually dictated by the facilities at the venue, i.e: commentators are found in control towers, dias' etc., which are fixed structures. If line power is needed, the amplifier position is limited by the length of available extension cords.

WARNING! *Check the integrity of extension cords before allowing anyone to use the system.*

Assuming that the amplifier location is determined, the next job is to arrange the horn speakers to cover the listening area.

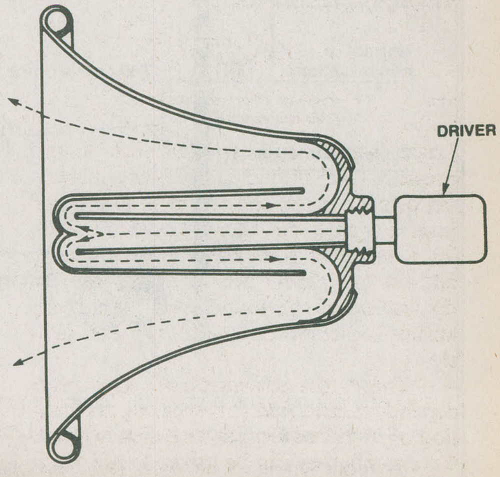


Fig. 3 A folded horn. These are physically smaller than the straight horn and have increased dispersion.

The simplest layout is the centralised cluster, where all speakers are together. This eliminates any time delay effects and simplifies wiring. To be effective, the cluster must distribute the sound so that nearby listeners are not deafened and distant listeners are able to hear the PA. This will require a high mount and possibly the use of straight horns to reach the furthest listeners.

Venues suitable for a centralised cluster are ovals and parks where the length-to-width ratio is less than about 2 to 1. The speakers should be positioned away from the commentary along the short end position and should point slightly downwards from the horizontal in a vertical stack. If they must be sited along the long side of a rectangular area then an additional vertical stack should be added and splayed about 75° apart.

It may be necessary to use long-throw straight horns to reach the furthest areas, these should be mounted on the top of the stack.

Additional 'side fill' horns are used to service listeners behind the main coverage area.

The vertical stacking results in a horizontal 'fan' of sound and reduces wasted acoustic energy upwards and downwards.

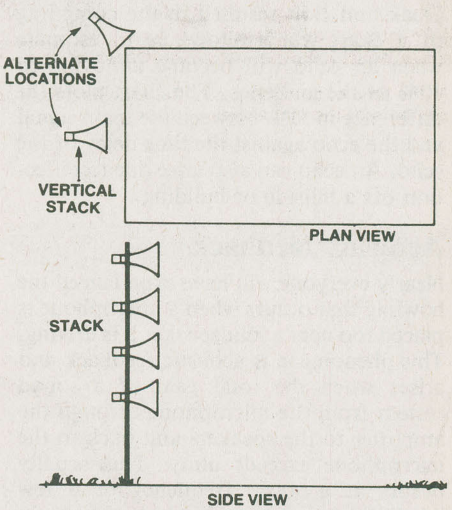


Fig. 4 The centralised cluster of speakers. Note the speakers should point slightly downwards.

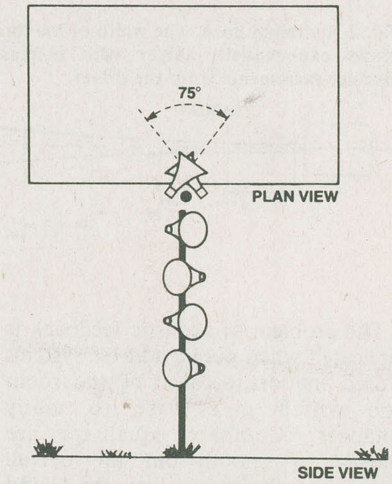


Fig. 5 Mounting a cluster along the side of the area to be covered requires the horn throats to be angled at about 75° and they must overlap.

Some venues are not suited to a centralised cluster. For instance, riverside events tend to concentrate the crowd in a thin rectangle along the bank. Such cases require multiple loud speakers, and care must be used in planning the sound sources to avoid annoying echo effects.

The best results are obtained by using a large number of speakers evenly spaced along the long axis operating at fairly low

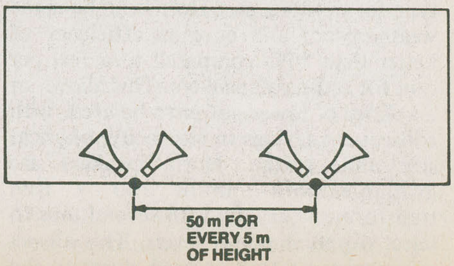


Fig. 6 Horn positioning for covering a long, narrow area.

PERCEIVED SOUND PRESSURE LEVELS

The human sense of hearing is stimulated by small variations in the air pressure at the ear. In order to perceive a sound the local pressure variations must conform to a limited range of frequencies and a minimum amplitude of vibration.

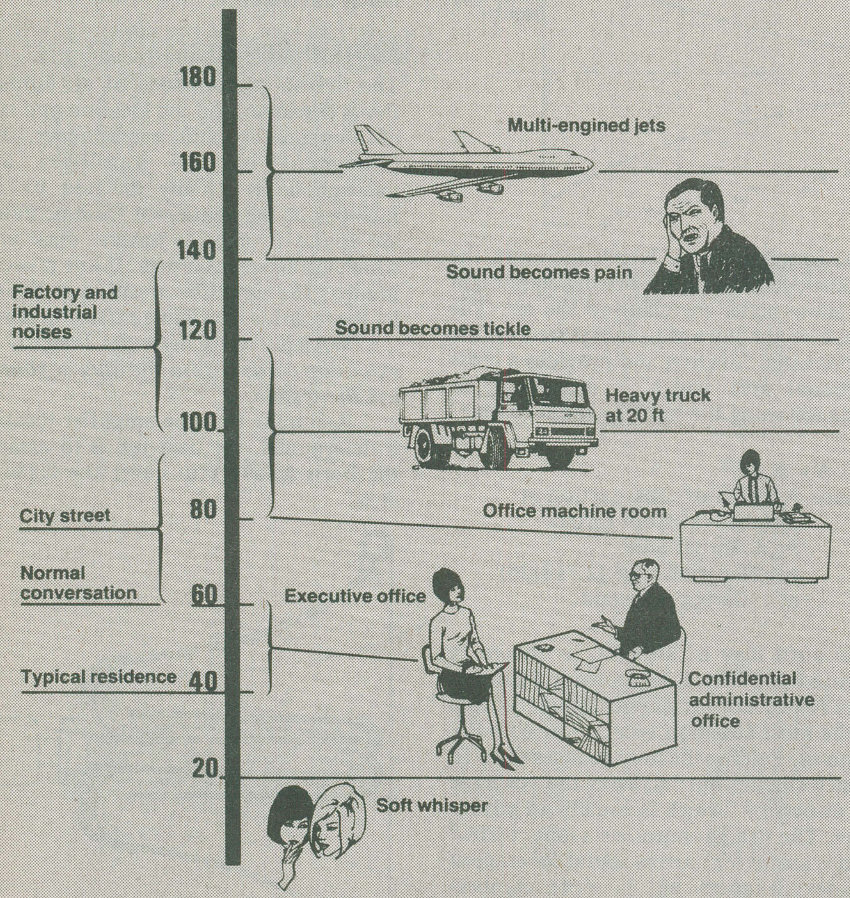
The amplitude frequency range is usually quoted as 20 Hz to 20 kHz, although the precise range depends on individual characteristics, particularly age and when the ears were last cleaned out! The minimum amplitude of pressure variations required for the perception of a 1 kHz sound in a young person's ear is about 20 uN/m² (or 20 uPa). Since this level represents a lower limit it is used as a reference for sound pressure levels and is given the value 0 dB SPL.

The largest sound pressure variation that can be tolerated without pain is about 100 N/m², which can be expressed as:

$$20 \log_{10} \frac{100}{20 \times 10^{-6}} \text{dB}$$

or about 134 dB SPL.

It is interesting to compare this to the variation in air pressure that often accompanies the approach of a storm, when a drop of 10 000 N/m² can occur in a few hours! Such slow changes in pressure cause our ears no distress because the inner ear is vented to the atmosphere through the Eustachian tube, which equalises the pressure on the eardrum.

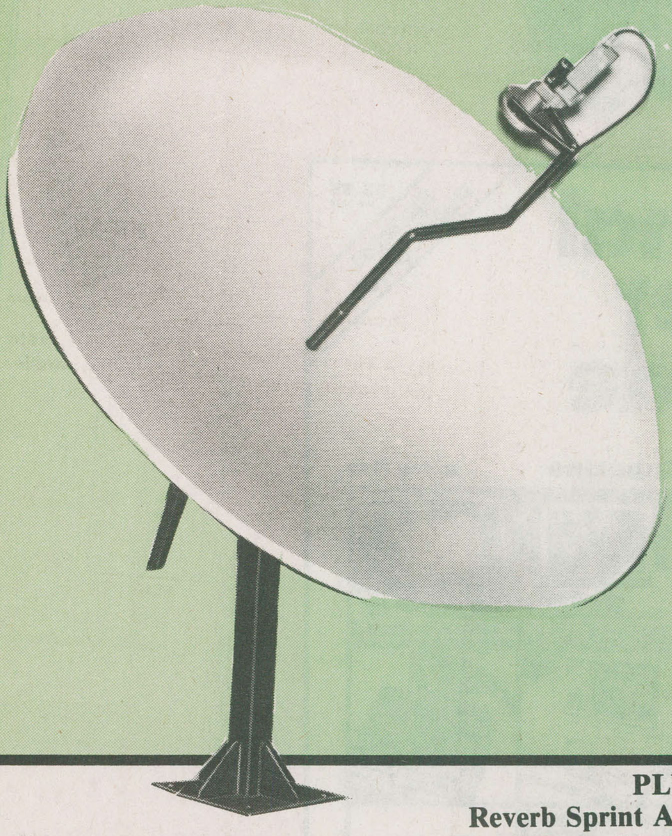


- For a sound to be perceptibly louder or softer, it must be changed by three decibels.
- A noise twice as loud or half as loud is a change of ten decibels.
- A reduction in noise of a few decibels in the low noise region (administrative office) is not significant. The same change at high sound levels (office machine room) is significant.

Continued on page 7

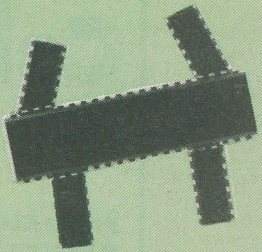
ETI next month

At the time of going to press, the articles mentioned are in an advanced stage of preparation. However, circumstances may result in changes to the final contents of the magazine.



Satellite TV Receiver Project

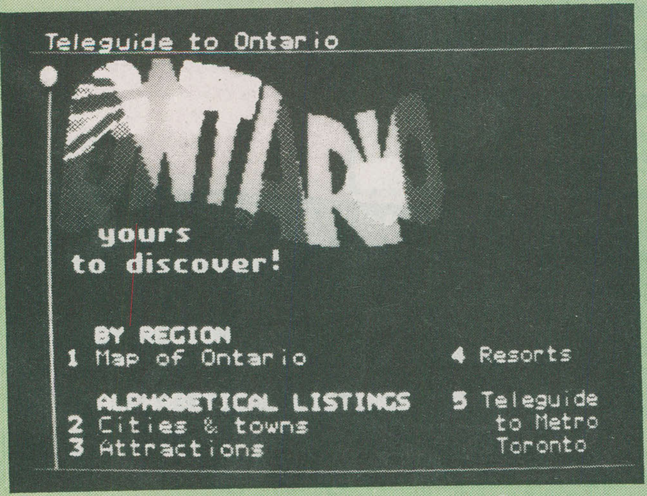
How to build your own Low Noise Amplifier, mount it on a disk antenna and connect it to your TV receiver; hints and application notes for optimum performance.



MPU Support Chips

You've read about the wonders of the computer-on-a-microchip. Then you open your home computer and find stacks of them in there - an explanation of what they do to keep your Micro-Processing Unit happy.

PLUS!
Reverb Sprint Amplifier Project!
Bomb Drop Sound Effects Project!
Audio Oscillator Project!
Instrumentation Techniques Part 2!

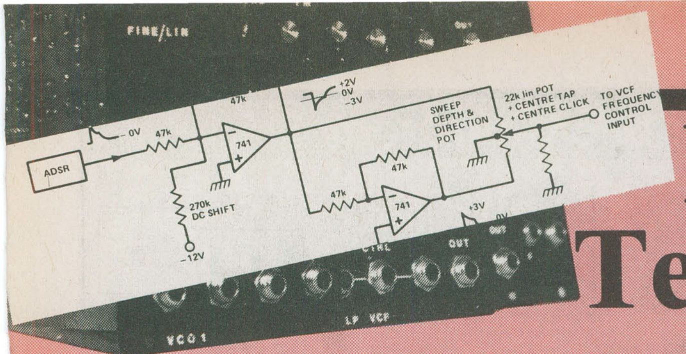


A Look At Cantel/Teleguide

We all thought Telidon might be a candidate for the White Elephant Hall of Fame, but it's out there working, and working well. Two of its users are examined in the next issue.

Electronics In Fine Art

Roger Allan describes the intricate techniques used by museums in restoration and forgery detection. A 32-bit 10 Megabyte computer, for instance, can easily tell the difference between a Renoir and a paint-by-number.



Instrumentation Techniques Part 1

Nowadays, measurement usually means digital measurement. Tim Orr looks at instrumentation techniques with details of how to use DVM chips to get all the basic ranges of a multimeter, and more!

THE FOLLOWING sections should give you enough information to go ahead and design your own digital multimeter, customised to give exactly the ranges and features you find most useful. We also look at techniques for measuring temperature and dealing with very small signals.

Dedicated DVMs

Intersil make a pair of DVM chips (Fig. 1, Fig. 2) that make life very easy if you want to measure and display a voltage. These chips are the ICL7106 and the 7107 and they seem to have become an industry standard. The first device is an LCD version and the whole lot consumes a mere 1 mA when running; it can run from a single 9V battery. The second device uses an LED display. The display may consume up to 100 mA, making battery operation a problem. Several companies make modules that contain both the DVM chip and a display. All you need to do is power it up and send it a voltage. It is, in fact, an 'instant' DVM module — no talent required.

The Intersil chips have a differential input with an input current of only 10 pA maximum, 1 pA typical. The devices have an auto zero facility so that they automatically cancel out any offset voltages at the input. The input sensitivity is 200 mV, but by connecting various amplifers, attenuators, RMS and dB converters and filters to the DVM chip a wide range of signal measurements can be performed.

Measuring Voltage . . .

Figure 3 shows the standard 1 megohm input impedance decade attenuator that is used in most digital multimeters. The very high input impedance of the 7106/7 produces negligible loading of the attenuator network. Figure 4 shows a standard four decade DC voltmeter circuit. If voltages below 200 mV are to be investigated then a preamplifier with low offset and drift characteristics is needed. The resistors used in the attentuator are standard E96 values and can be obtained with a 0.5% tolerance.

. . . Current . . .

Figure 5 is a current meter circuit; the current is made to pass through shunt resistors. This sets up a DC voltage (no more than 200 mV) which is measured by the DVM chip. The input is protected by a diode bridge that pops the fuse when the input voltage exceeds 1V8 (three diode voltages) and the current exceeds 3 A. If you could pass unlimited current through the resistor network then you would probably end up with a fire!

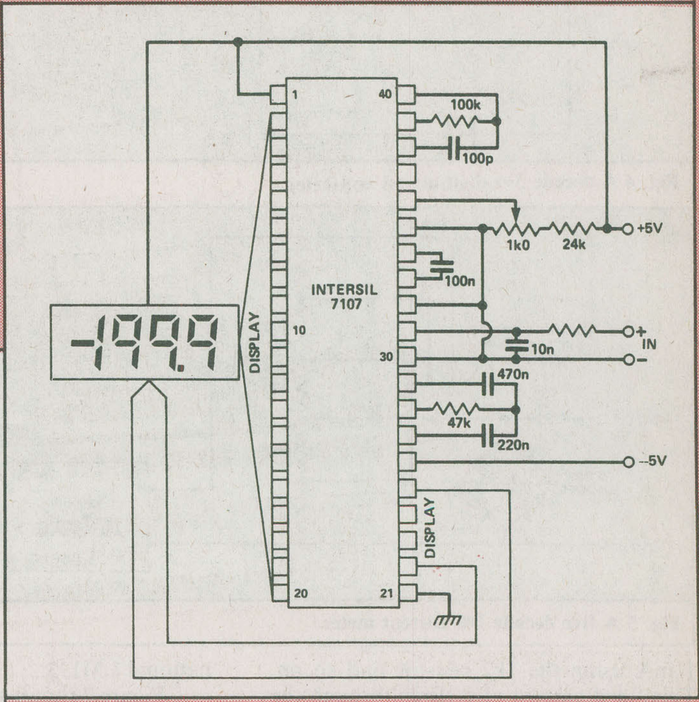


Fig. 2 The Intersil ICL7107 with LED display.

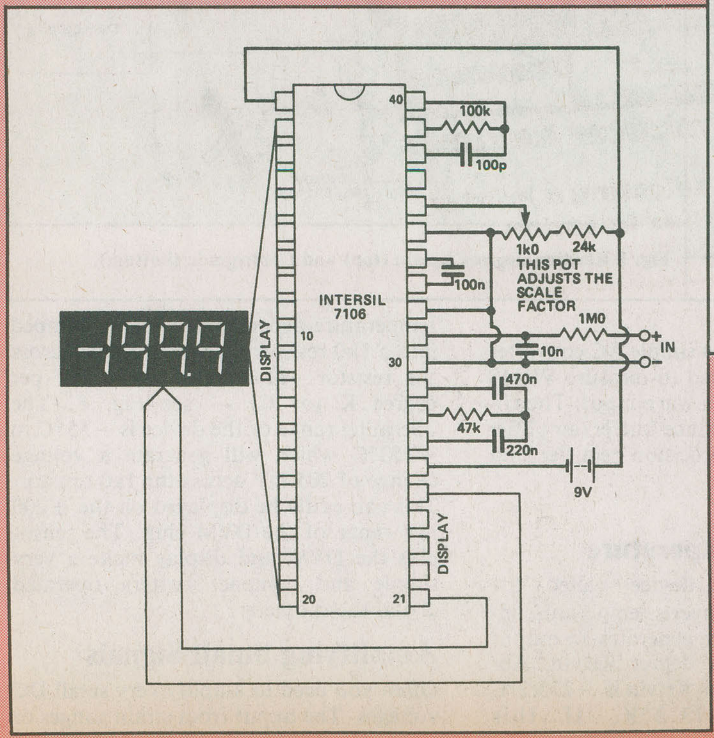


Fig. 1 The Intersil ICL7106 with liquid crystal display.

. . . And Ohms

Figure 6 is an ohmmeter circuit. The 741 op-amp generates a precision and stable −1V2 DC reference voltage which causes a fixed current to flow into the virtual ground input of the LF355; the current will be 10 mA using the 120 ohm resistor,

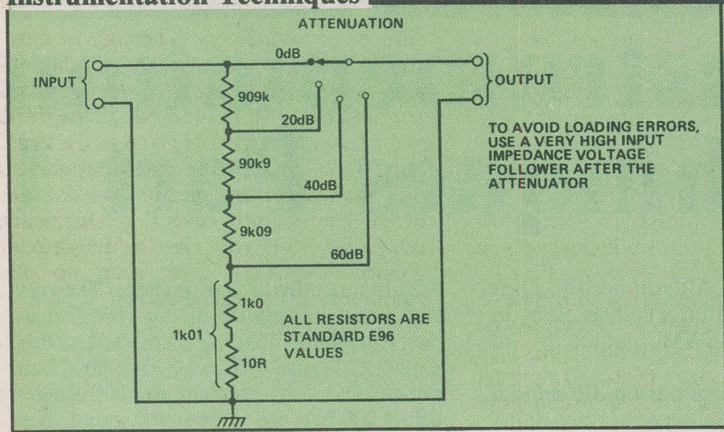


Fig. 3 A 20 dB step attenuator.

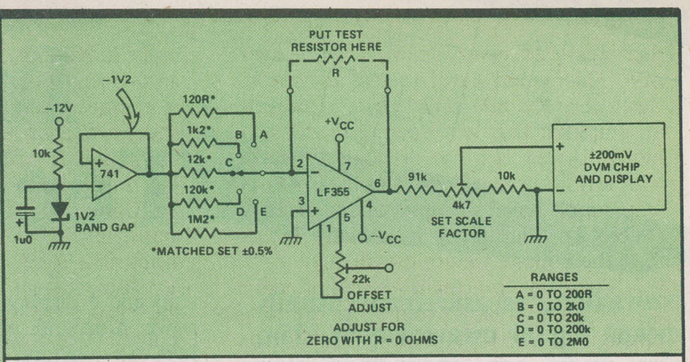


Fig. 6 A five decade ohmmeter.

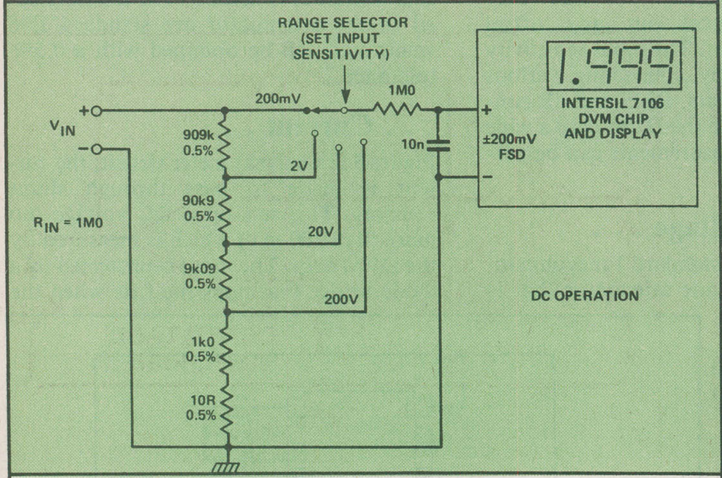


Fig. 4 A decade 3½ digit digital voltmeter.

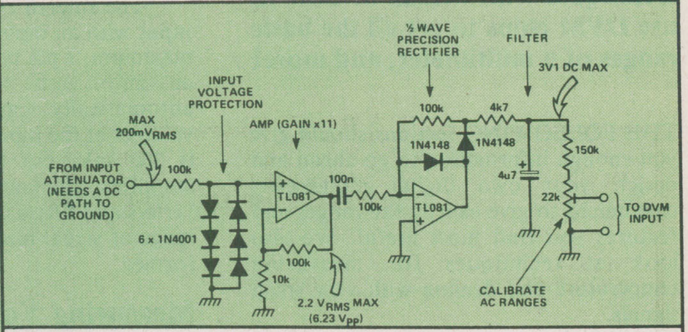


Fig. 7 An AC voltage and current converter. This is only accurate for sine waves.

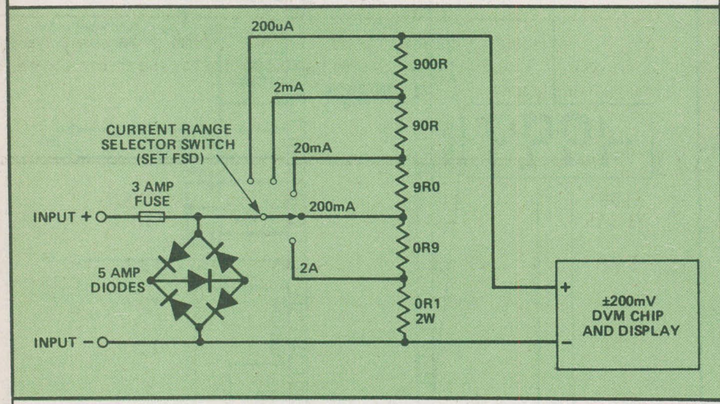


Fig. 5 A five decade DC current meter.

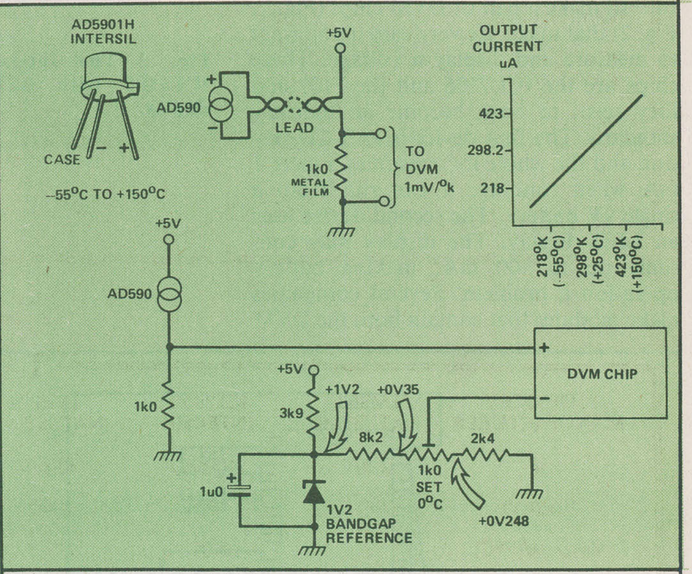


Fig. 8 Reading degrees Kelvin (top) and Centrigrade (bottom).

1 mA using the 1k2 resistor and so on. This fixed current also flows through the test resistor which is the feedback route for the LF355 and in doing so sets up a voltage that in linearly proportional to the value of the test resistor. At 'full-scale-deflection' the output of the LF355 is 2 V which is attenuated to 200 mV; this voltage is then fed to the DVM chip. The LF355 is a JFET op-amp which has a small input current and offset voltage and low temperature drift characteristics. Even so it is better to run the output at 2 V and then attenuate it to 200 mV, because this also attenuates any residual offsets and other errors. The bandgap diode is a national LM113.

Figure 7 shows a simple AC converter circuit. It can be used to measure VRMS and IRMS for a sine wave input. The circuit is a high impedance buffer/amplifier with a half-wave precision rectifier and smoothing circuit.

Measuring Temperature

Intersil makes a device called the AD5901H which converts temperature into current; the device generates an output current of 1uA per degree Kelvin. Absolute zero in degrees Kelvin is −273.2°C and so 0°C = 273.2°K. If this temperature-dependent current is dumped into a 1k0 resistor than the voltage across the resistor will increase by 1 mV per degree K (or C) — see Fig. 8. The operating range of the device is −55°C to +150°C which will generate a voltage change of 205 mV across the 1k0 resistor. This can easily be displayed on the ±200 mV range of the DVM chip. The sensor plus the DVM and display make a very simple and compact battery operated digital thermometer.

Amplifying Small Signals

Often you need to amplify very small DC voltages. The ouput from strain gauges or

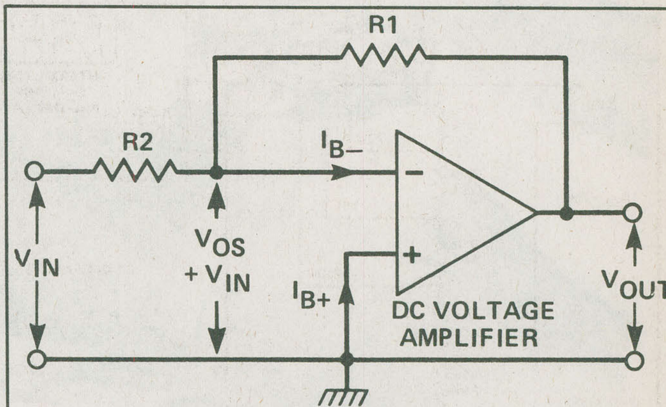
thermocouples is very small, often below 1 mV. This would hardly cause any movement in a 200 mV DVM chip. However, an amplifier that will operate in the sub-millivolt area is quite difficult to make with any accuracy. For example, a 741 op-amp might have an input offset of 2mV (Table 2). This error is actually bigger than the voltage we are measuring!

There are four main sources of error. I_B, the input bias current, has to flow through R1 and R2 and in doing so upsets the gain equation. Note that I_{B-} is not exactly the same value as I_{B+}! V_{OS} is the input offset voltage which represents a DC input imbalance. This also upsets the gain equation. Furthermore, V_{OS} has a temperature coefficient V_{OSTC} which is the maximum change in V_{OS} per degree C. So the amplifier will drift with temperature. V_N is the input noise voltage, which is multiplied by the fixed gain on the amplifier. If the noise is similar in amplitude to the input voltage then you are going to get noisy readings. Finally, the input offset voltage drifts with time — it ages! Very few manufacturers provide information regarding this parameter.

The selection chart (Table 2) shows a range of instrumentation and ordinary op-amp error parameters. The way to overcome these errors is to use a suitable op-amp rather than to use a low performance part and to try and cancel out all the drifts and offsets. The details given in the chart only show some of the many parameters that manufacturers specify. Devices are often graded into several performance categories, so if you want to design high quality amplifiers then refer to the manufacturers' detailed data.

TABLE 1

DEVICE	E IN uV RMS (AVERAGE OF SEVERAL SAMPLES)	NOISE LEVEL RELATIVE TO NE5534 IN dBs
NE5534 (SIGNETICS)	0.59	0
RC4136 (RAYTHEON)	0.87	+3.4
RC4739 (RAYTHEON)	1.00	+4.6
RC4558 (RAYTHEON)	1.05	+5.0
TL081 (TEXAS)	1.61	+8.7
741 (VARIOUS MANUFACTURERS)	1.72	+9.3



$$V_{OUT} = \left(V_{IN} \times \frac{R1}{R2}\right) + \text{ERRORS}$$

Fig. 9 Choosing a precision op-amp. Table 1 (left) gives some typical noise results, Table 2 (below) shows typical values for the errors shown in the above diagram.

TABLE 2

DEVICE MANUFACTURER	LM363 NAT. SEMI	ICL7650 INTERSIL	LF355 NAT. SEMI	TL081 TEXAS	741 —	725 —	OP-27A/E PMI
I_B	2 nA	10 pA	30 pA	5 pA	80 nA	42 nA	10 nA
V_{OS}(uV)	30	1	2000	5000	2000	500	10
V_{OSTC} (uV/°C)	2	0.05	5	20	2	0.6	0.2
NOISE (V_n) (nV/√Hz)	12	2 uV_{pp}	20	20	14	9	3
LONG TERM DRIFT	—	100 nV/month	—	—	—	—	200 nV/month
COMMENTS	A_V = 100	Chopper stabilised op-amp	JFET op-amp	JFET op-amp	Bipolar op-amp	Instrumentation op-amp	Ultra-low noise precision op-amp

ETI

Tanover

Don't burn . . . turnover with the Tanover!

WHEN BASKING in the delightful rays of the sun, whether on some warm beach on a far-off mysterious island or in your slightly cooler garden, it is all too easy to drift away and lose all track of time. For many of us, whose main source of brown skin is a bottle (or rust!), this can be a very painful experience. This is where the Tanover comes into its own. Just set it to the desired time, press the studs and relax. When it beeps the first time, turn over to toast your other half, but at the second beep it is time to 'cover up'. Start with a short exposure and work up 'Tan-time' over several days for an even and relatively painless tan.

In order to keep the device as cheap and simple as possible, only two CMOS ICs are used. IC1 is a 40106 which consists of six Schmitt trigger inverters in one package. The main property of a Schmitt trigger is that its output changes state at two different voltages — one when the input is rising and another when it is falling. This makes it ideal for oscillators and timing circuits. Also since IC1 is a CMOS device, we can use large values of resistance and small values of capacitance to achieve the required time constants.

IC2 is a 14 stage counter which divides the input frequency by up to 16,384. This allows us to use reasonable values of R and C in the oscillator, while still achieving long time delays. The sound output from the device is provided by a small piezo-electric sounder, driven by an oscillator, IC1e, and inverter (IC1d) in such a way as to get the maximum output from the available supply voltage. Ideally, we would have liked the device to be powered from solar cells, but very special, expensive circuitry would have been required to run it from one cell and the cost of several cells in series was felt to be too high. Therefore, we have shown it powered from a 5V6 camera battery which should last a long time as, once the device has finished its work, its current consumption is very, very small.

The Circuit

IC1a and associated components form a touch activated switch; when a finger is placed across the contacts, C1 is discharged via R1 (and the finger), the output of IC1a goes high and the output of IC1b goes low. This high level from IC1a is used to reset IC2 to the 'all zeroes' state and make the device ready to start counting.

When the finger is removed from the contacts, C1 charges via R2 and after a short delay, the output of IC1a goes low thus enabling IC2 to count clock pulses from oscillator IC1c. At the same time the output of IC1b goes high causing the output to bleep for a time determined by C3, R9 and R10 — more of this later.

After 4096 clock pulses, IC2 pin 2 will go high, causing the output to bleep for a time determined by C4, R8 and R10. Another 4096 clock pulses later, IC2 pin 3 will go high and this will also cause the output to bleep, the time being determined by C5, R7 and R10.

Now, with IC2 pin 3 high, the oscillator IC2 can no longer operate and the whole circuit will go into a stand-by condition, in which it draws very little current.

The Sound Generator

After a positive edge at one of the relevant outputs (from IC1b, IC2 pin 2 or 3), the input to IC1f will be high enough to make its output go low. When this happens, the oscillator formed by IC1e, C6, D5, R11 and R12 will operate and the output from this is used to drive the piezo-electric sounding device. In order to maximize the sound output, the oscillator output is inverted by IC1d, thus doubling the available drive voltage and quadrupling the power.

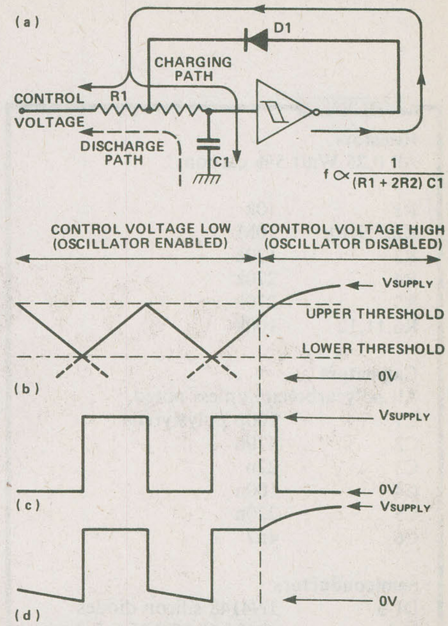


Fig. 2(a) The circuit of a gated oscillator; (b) waveform at the input of the Schmitt trigger; (c) ouput from the trigger; (c) voltage at the junction of R1 and R2.

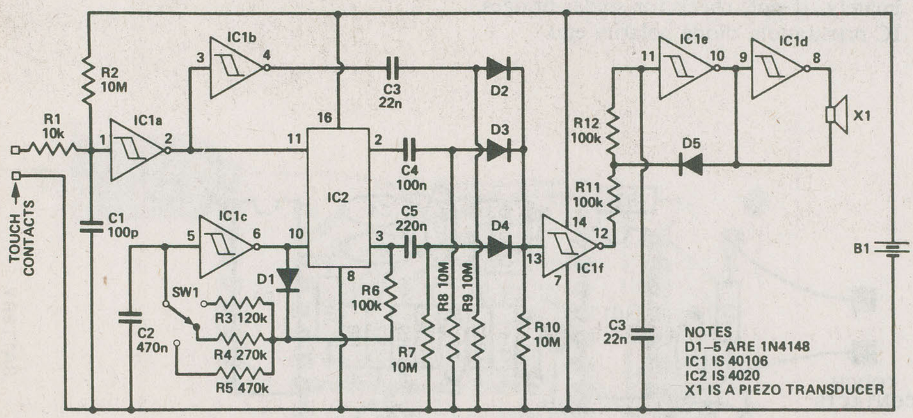


Fig. 1 The full circuit diagram.

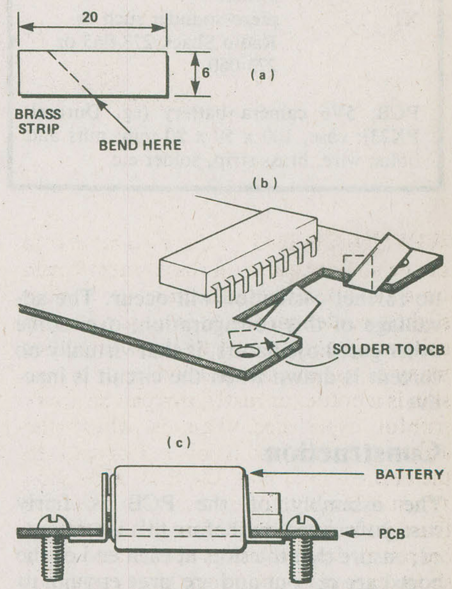


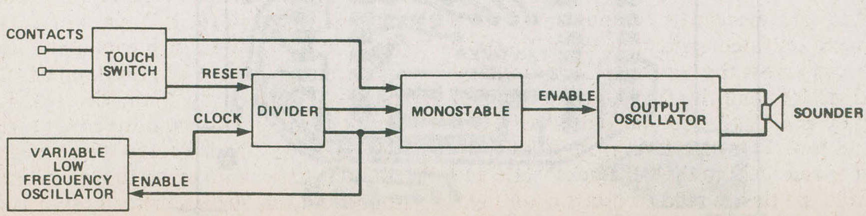
Fig. 3(a), (b) Making and assembling the battery connections; (c) the battery in place.

HOW IT WORKS

Touching the contacts causes the divider to be reset to all zeroes and enables the oscillator (with a low pulse). On releasing the contacts, the divider will start counting and the monostable is triggered. The result of all this is to cause the output oscillator to produce a 'bleep' from the sounder.

When the divider has counted 4096 clock pulses, one output goes high and triggers the monostable. This produces another 'bleep' from the sounder (for a longer period).

After a further 4096 pulses, the other output goes high, setting off a third and final bleep (the longest of the three). The second high output from the divider also disables the oscillator, preventing any further action until the reset is triggered again.



The Oscillators

There are two oscillators in this circuit, both of the same type. The basic mode of operation is that of a simple Schmitt trigger with RC feedback (Figure 2). However the output from the device is connected via a diode, D, so that capacitor C can only charge *up*. In order for the capacitor to *discharge,* the control input must be low; if the control input is high, the capacitor will charge to near the supply voltage and

PARTS LIST

Resistors
All 0.25 Watt 5% carbon.

R1	10k
R2,7,9,10	10M
R3	120k
R4	270k
R5	270k
R6,11,12	100k

Capacitors
All polycarbonate unless noted.

C1	100p polystyrene
C2	470n
C3	22n
C4	100n
C5	220n
C6	4n7

Semiconductors

D1-5	1N4148 silicon diodes
IC1	40106 CMOS Hex Schmitt trigger
IC2	4020 CMOS 14-bit binary counter

Miscellaneous

SW1	miniature 3-position slide switch
X1	piezo sounder such as Radio Shack 273-065 or 273-060

PCB; 5V6 camera battery (eg. Duracell PX23); case, 100 x 50 x 20 mm; nuts and bolts; wire, brass strip, solder etc.

no further oscillation will occur. The advantage of this configuration, over some other gated oscillators, is that virtually no current is drawn when the circuit is inactive.

Construction

The assembly of the PCB is fairly straightforward but before this is attempted, ensure that the slots at each end of the board are cut out and are large enough to clear the battery and switch.

Now assemble the PCB, not forgetting the wire link for the negative supply. The battery connectors are made from two pieces of springy brass strip of the type often found on older 4½ volt batteries, although anything similar would do. They are bent at an angle of about 45°, in opposite directions, so that when soldered in position, they will hold the battery and make good contacts (Figure 3).

Although sockets are normally recommended for integrated circuits, in this project it may be found that there is insufficient clearance, when assembled, if they are used. If this is a problem, the height of the mounting pillars in the box may be reduced by judicious use of a large drill!

The next step is to mount the switch in the box. This may be either in the end, as in our model, or in the lid if space is too restricted. Now drill a 5 mm hole about 35 mm from the battery end of the lid, to allow the sound out, and then two small holes about 40 mm from the other end to take the touch contact screws. Stick the piezo sounder in position inside the box lid and solder its wires to the PCB. Now, using fine insulated wire, connect the switch and touch contacts to the board.

The board is secured in position with short bolts and, with the BATTERY INSERTED THE CORRECT WAY ROUND (negative nearest link), to the top of the box may be eased on and the wires poked into available spaces until it fits. The device should now be functional with the switch positions corresponding to 20 mins, 40 mins and 60 mins, approximately. If not, check for solder bridges, IC orientation, diode polarity etc!

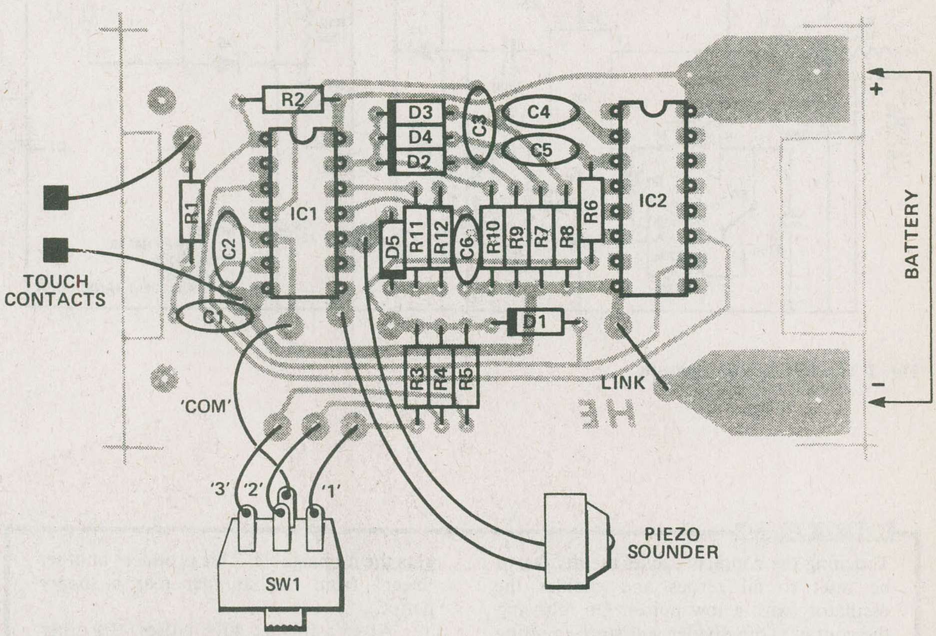
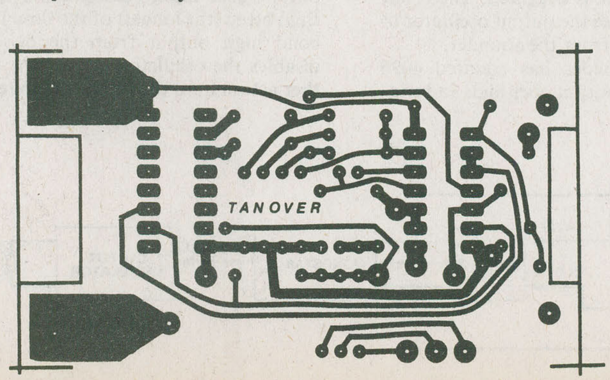


Fig. 4 The component overlay.



Tanover

To start the device, place a finger firmly on the two contacts and then release it. A short bleep should be heard, indicating that the device has been reset. Some time later a longer bleep will occur, and this is the time to turn over and bronze the other side. A similar time later, another even longer bleep indicates that it is time to cover up.

When first taking the sun, use the shortest time and after a few days, work up to the next stage. The number of days on each setting depends on the latitude at which you are sunbathing and your individual sensitivity. Time periods other than the preset 20, 40, and 60 minutes may be obtained by varying the values of R3, 4 or 5 if required. Very sensitive skin may burn even at 10 minutes exposure in hot weather.

P.S. Wet your finger if it is difficult to start.

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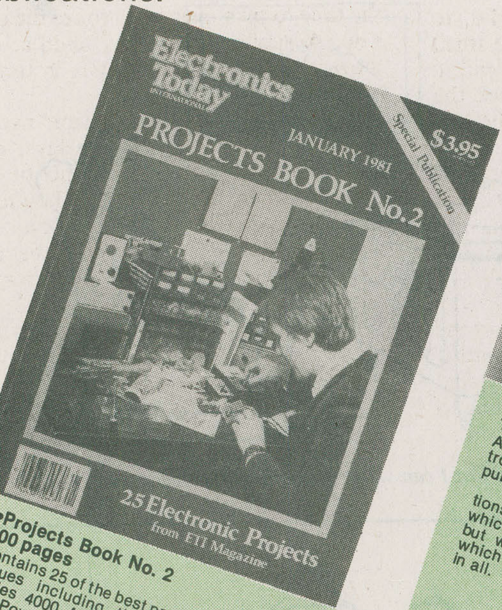

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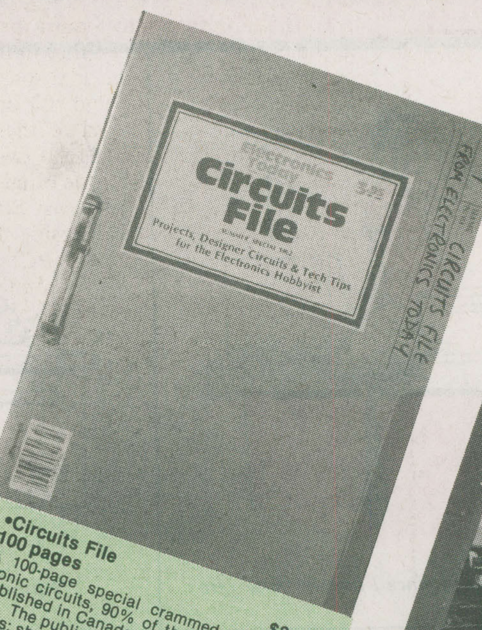

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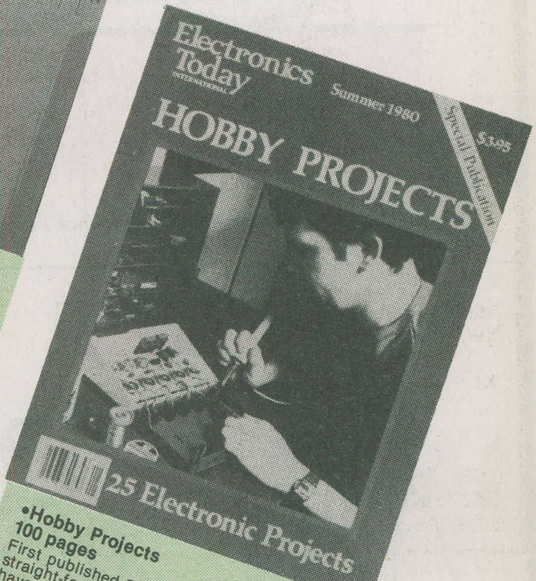

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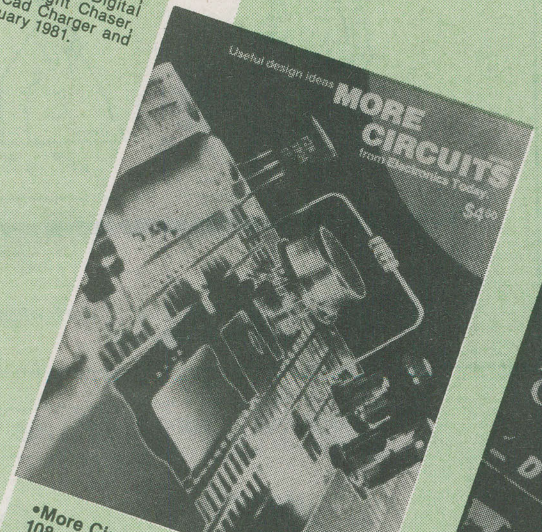

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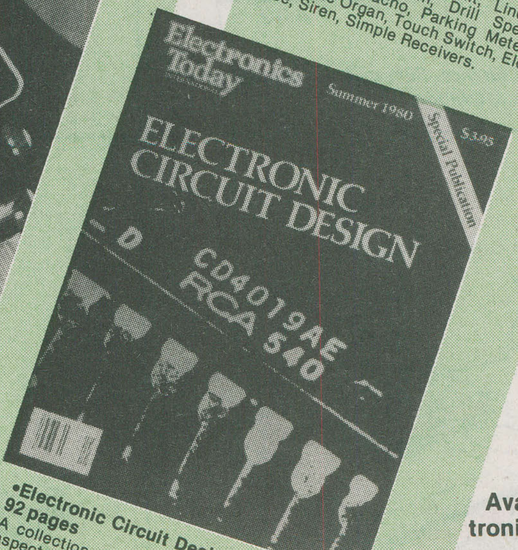

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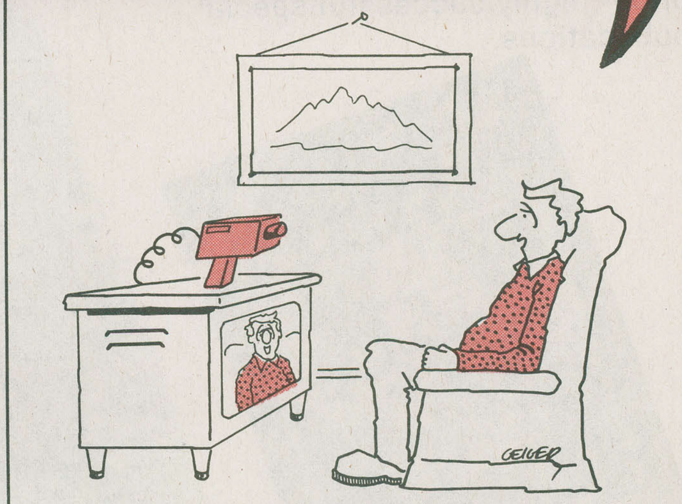

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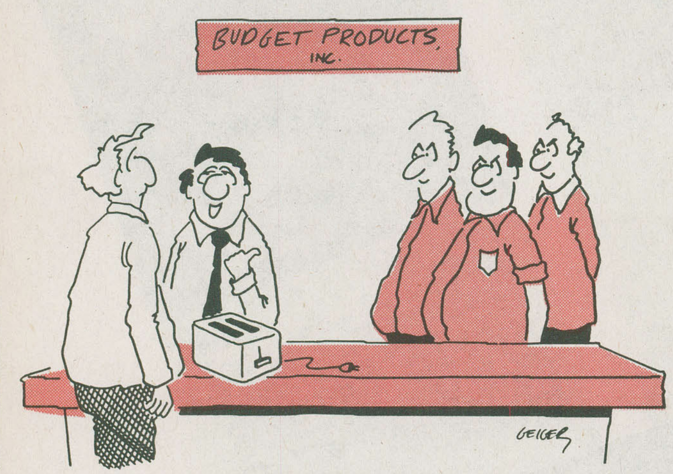

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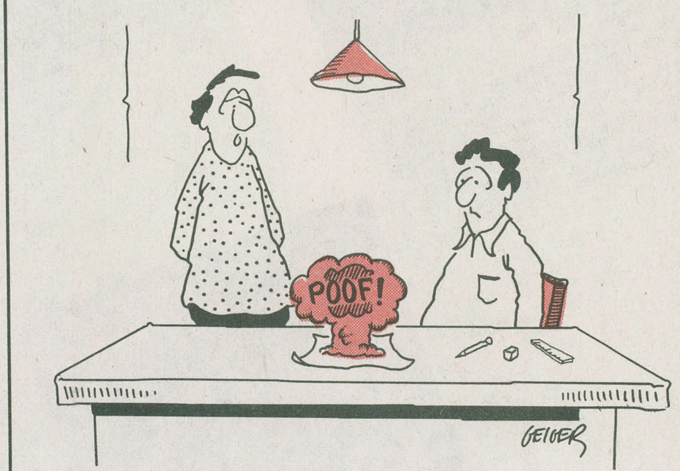

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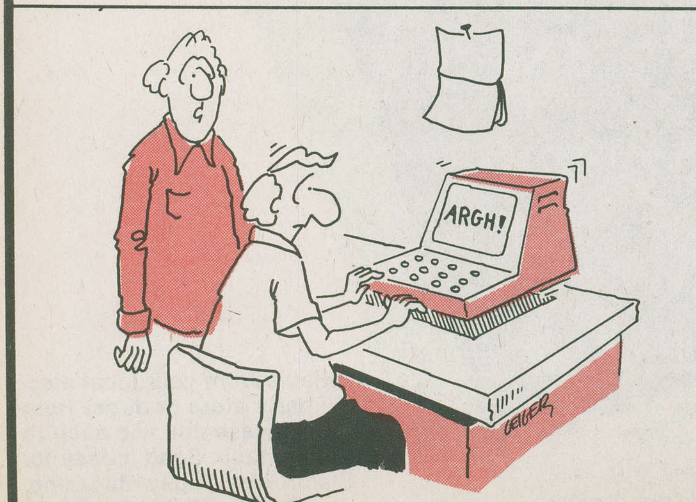

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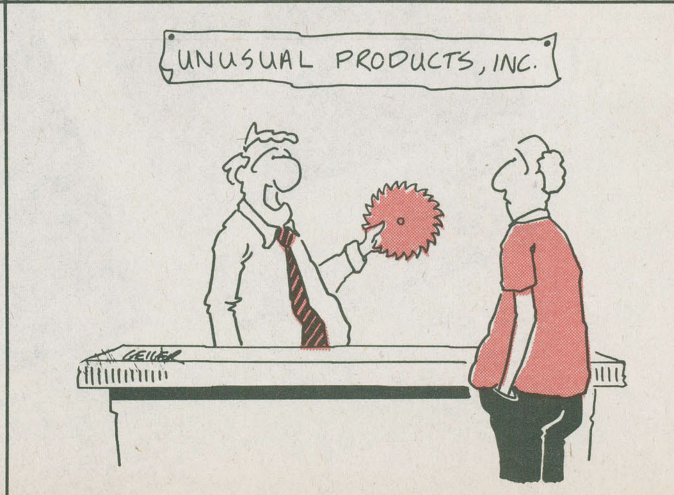

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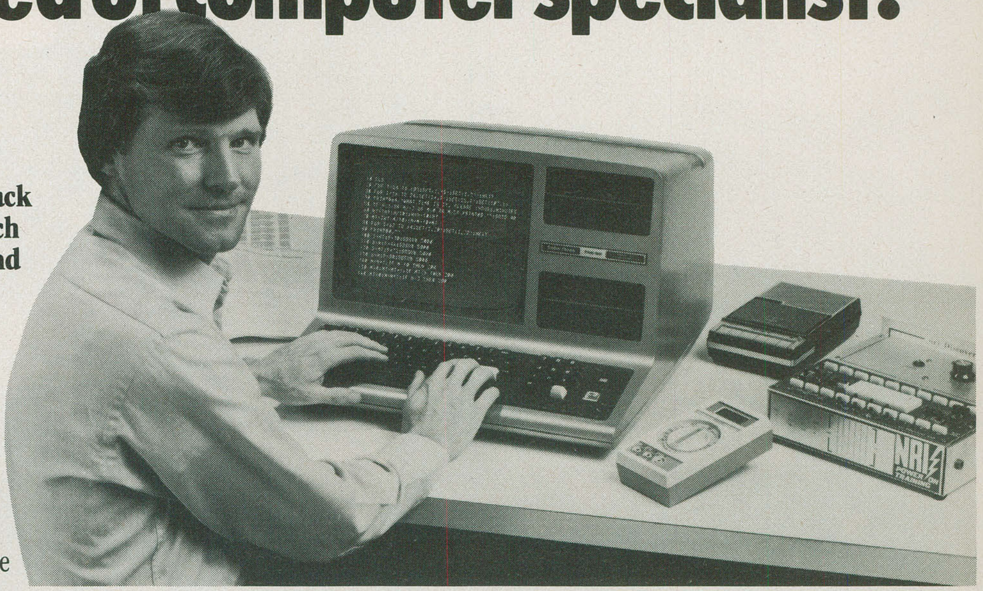

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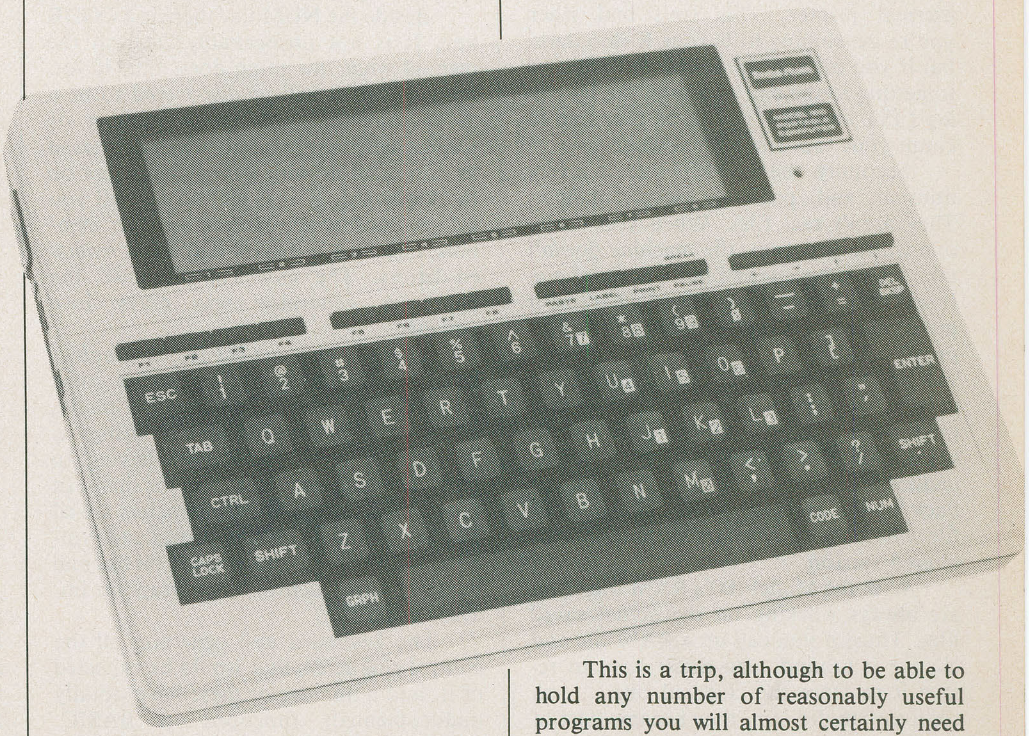
TRS-80 Model 100 Review

A liquid crystal display and Microsoft BASIC make this one of the more useful of the portable models. Too big for your pocket, it might be called a lap computer.

by Steve Rimmer



DEPENDING UPON just how you want to look at it, the TRS-80 Model 100 could be the Sinclair for rich people or the Osborne for midgets. Resembling an electric typewriter that's been flattened by a punch press, it is an interesting departure from the half megabyte sixteen bit behemoths that have been springing up at the corner computer shop. It's tiny, powerful, unusual . . . and ridiculously expensive.

Technology is such a gas when it gets bizarre.

ASCII And Ye Shall Receive

The Model 100 is about the size of a fat coffee table book. It isn't pocket sized unless you're the jolly green giant, but it can certainly fit in a brief case. It has a full size QWERTY keyboard of reasonable quality with a number of novel innovations, including eight programmable function keys, a cursor mover section and a switchable numeric pad. It does not use a CRT; perhaps the most interesting thing about this contraption is that it talks to you via a huge liquid crystal matrix that can display eight lines of forty characters. This, of course, makes it totally portable. It can run on four penlight batteries for twenty hours or from an AC adapter until you forget to pay the light bill.

The LCD display driver has a timer in there somewhere which blanks the screen if there has been no keyboard activity for a few minutes to keep the batteries mellow.

The computer is based on the Intel 80C85. This is a CMOS version of the 8085, an enhanced 8080 with pipeline architecture and suchlike. As such, it is easily programmed if you want to get into machine code . . . you may not like the idea now, but you'll come to it in the fullness of time.

The box has an internal nicad cell which keeps its CMOS RAM alive even if you steal its batteries to run your flash gun. As such, it retains its programs with the power off. There is also a cassette interface to provide for heavier long term mass storage.

There is all manner of unimaginable splendor inside the box . . . software to do things you probably don't now realize you want done. Immediately on powering up you will be presented with a menu of the available options. These include BASIC, plus several utilities . . . we'll scrutinize them in a second. This display also gives you the time . . . there's a clock in there (well, why not) and the number of bytes of RAM you have to play with. This is about five K on an unadorned Model 100, although it can be expanded out to twenty-nine K.

One of the things that will initially catch the eye about this menu is that there is a large number of blank spaces on it. There's a reason for this . . . you can add to it. Because the storage medium of the system is essentially non-volatile, you can use it as you would a disk or cassette. Programs can be SAVEd as RAM files, tucked away in memory and forgotten about . . . but their names remain in the menu. Thus, you can run a program in RAM by calling it from the menu.

This is a trip, although to be able to hold any number of reasonably useful programs you will almost certainly need some memory expansion.

The Model 100 also provides a socket beneath one of its many trap doors to allow the plugging in of customized ROMs. This would allow the system to hold special function machine language programs.

Basically Speaking

The BASIC for the system will prove quite familiar if you've used a computer before. It's genuine Microsoft, and most of the usual stuff is in there somewhere. In addition, there are a few things that are unique to this particular creation. Most of the capacities of the thing are nicely supported in the BASIC.

The BASIC has been well thought out, and is eminently usable. Six of the eight function keys come already programmed to do common tasks with single keystrokes, to wit, FILES, LOAD, SAVE, RUN, LIST and return to the MENU. The keys can be programmed from BASIC should you have loftier things in mind for them.

Programs can be typed in and edited in the usual manner. There's an EDIT function, rather than screen editing, a bit less convenient than it could be, but still cool. All of the common BASIC syntax is supported: spaces are ignored, "?" means PRINT, and so forth.

TRS-80 Model 100 Review

In playing with the BASIC, several things crop up. First off, the LCD display is glacially slow when compared to a CRT. It is more along the lines of a paperless thermal printer. This isn't bad when you're developing little four K doo dads, but if you expand the RAM and are used to getting to the end of a long file by typing LIST and looking up, be prepared to count your toes for quite a while.

Secondly, the RAM files act in a very unusual, and, probably clever, manner. They aren't real files. When you create one with a program, the machine doesn't take your program and put it somewhere. It sets up a pointer into RAM where your program is and gives it a menu entry. This prevents additional programs from overwriting your first file, but it also has a curious side effect. If you create a program on a regular computer and save it, say on a disk or tape, you have created an unalterable copy of your file. If you call it back to the computer and change it the file will not be touched unless you save the altered version.

With the Model 100's RAM files, you are always working on the actual saved files. Thus, if you call up a RAM file and change it around, you don't have to resave it to store the changed bits . . . as soon as you did 'em, they became part of the file.

On the other hand, if you didn't like the changes you made you can't just trash the file and call the old version back.

The keyboard, too, has its uniquenesses, some of which are availed of minimal documentation. Imbedded in the alpha keys is a secondary numeric pad. This is in addition to the usual top row of number keys. Normally these keys produce the alpha characters we have all come to speak of in polite conversation. However, by placing your hairy finger upon the "NUM" key 'til it clicks, they mysteriously change into a numeric pad for entering data. Quite clever, this.

Beside the NUM key there is a CODE key. It is not unspeakably clear in the manual what this thing does, but, if you mess with it it will be discovered to be a super shift that produces a number of foreign language symbols when depressed in conjunction with other characters on the keyboard. If it is shifted as well you get yet another set of even stranger symbols, like "trade mark" and a few reversed letters. The guy who designed the character generator was crazy into umlauts.

There is also a GRPH, or graphics key, which allows you to access some graphics characters. This is quite handy, as they can thus be included in strings as actual characters, instead of having to print character code numbers for them. In the unshifted state, these characters are all manner of unusual little beasties and symbols. Hit the shift and you get blocks and lines for constructing block graphics images. What fun!

The keyboard also generates all the control characters that would be expected of it, and a number of these have (totally undocumented) functions in BASIC. CTRL X erases a line without entering a carriage return . . . essentially it just backspaces to the left hand side of the screen. Control U does the same thing . . . by the convention of these things, it should leave the line on the screen, but ignore it. CTRL S will halt the display on the screen until a second CTRL S is hit.

The BASIC has a number of additional frills built into it. One of these is the ability to make noises on the built in squeaker-speaker. This doesn't sound like a particularly profound trip, but most systems that are limited to the control G bleep don't give you this capacity unless you scare up the machine code manuals. In fact, it isn't even particularly hard to get along with. There's a SOUND command that loads a divisor value into the counter that determines the pitch of the sound, and another into the one that handles the duration. The pitches are a bit unwieldy, but the manual has a list of the numbers that approximate a tempered scale.

This is a typical SOUND program:

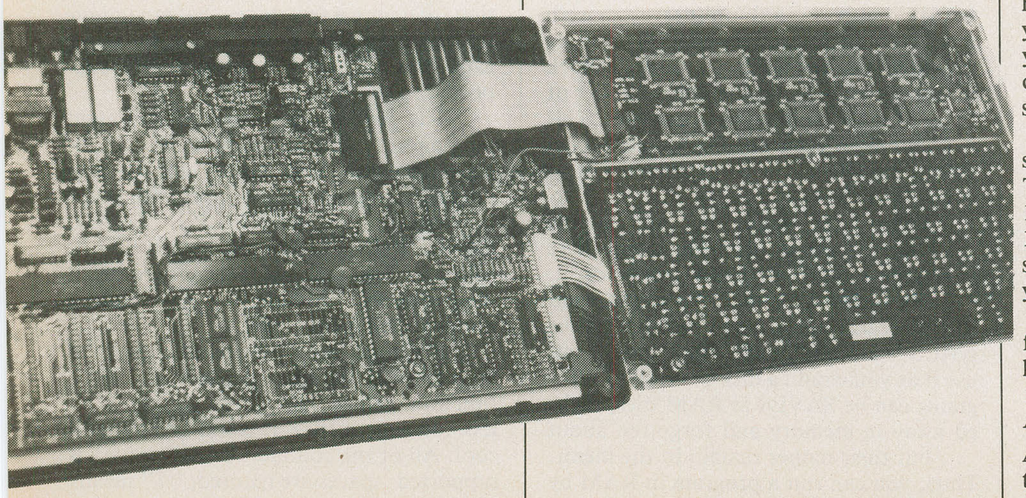
```
10 REM SOUND!!!
20 READ S
30 IF S=0 THEN 100
40 SOUND S,10
50 GOTO 20
100 END
500 DATA 2348,2092,1864,1567,1758,1758
510 DATA 1396,1567,1567,1174,1244,1174
520 DATA 3134,2793,3134,3516,3718
1000 DATA 0
```

It sounds like a digital watch gone mad. The 10 in line 40 is the duration of the notes. If you change it to a 5 things really clip. The data statements are the notes produced . . . this lot plays a bit of a BACH chorale. Bach did a number of chorales, largely to keep the horses from escaping.

Another facility of the BASIC is the opportunity for the programmer to set up "interrupts". These aren't real interrupts, but, rather, software equivalents. You can use these to interrupt the normal running of a program to do something of a higher priority. For example, let's say that you had programmed the computer to play Gopher . . . this is essentially like Frogger except that it involves rodents and steam rollers. Knowing that this game is pretty heady stuff, and that you are likely to lose yourself in it , you might want to have yourself reminded when it's time to check on the temperature of the reactor core. No sweat.

All you gots to do is make an early statement of your program ON TIME$="10:30" GOSUB 1000, where 10:30 is when you want to be alerted and 1000 is a subroutine that bleeps and squacks and plays a Bach chorale to get your attention.

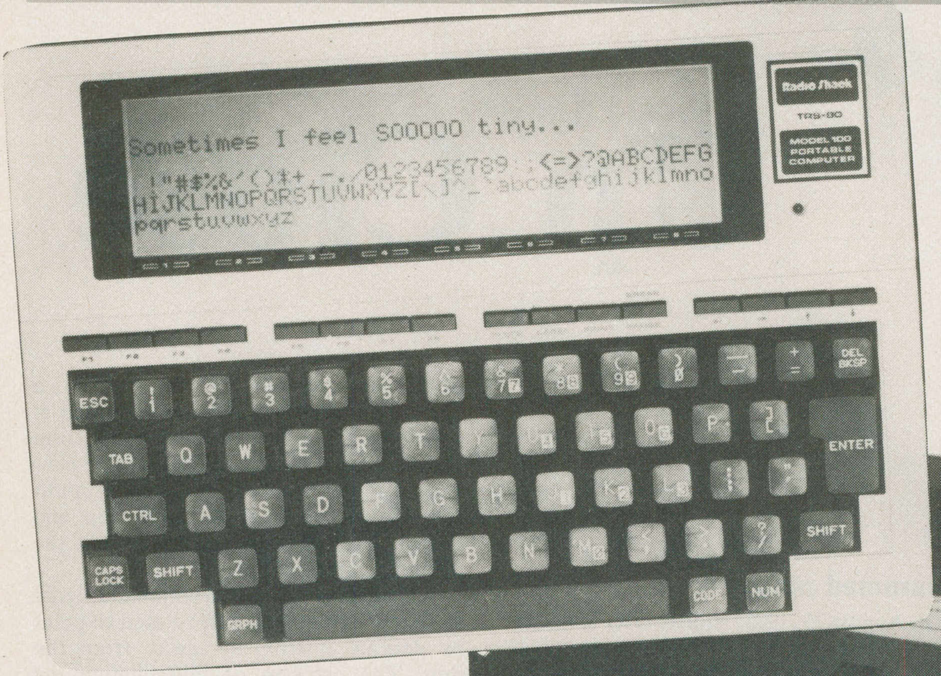
You can set these interrupts to look for time, activity at the modem port, the hitting of a function key or an error.

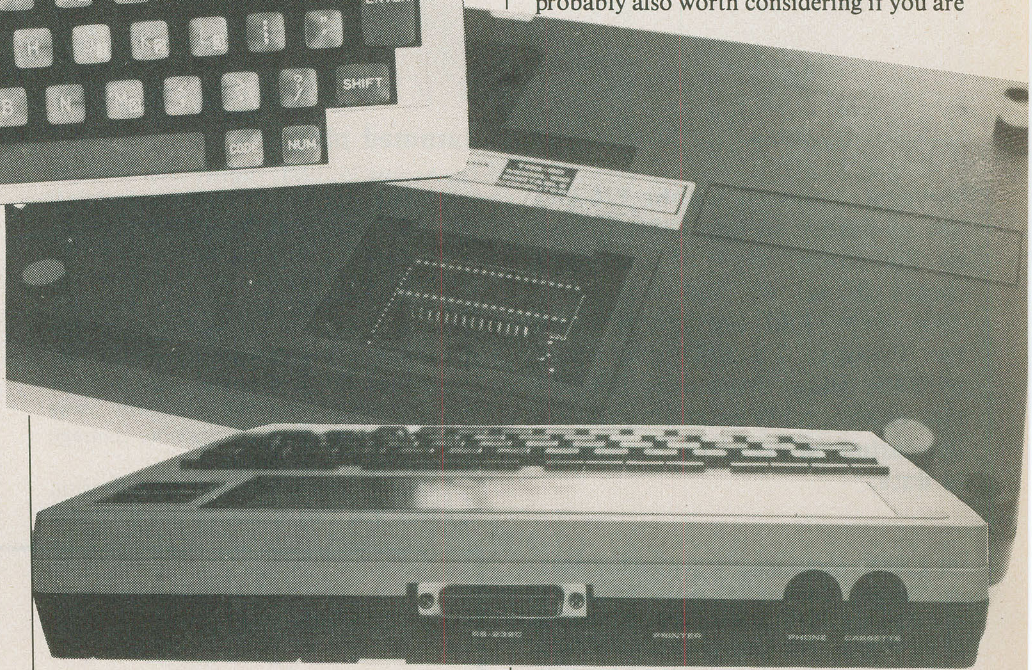


And Now, A Few Words . . .

As alluded to earlier, you can do other things with the Model 100 once you get weary of programming it. If you get back

TRS-80 Model 100 Review





to the menu and move the cursor over the file entry TEXT you turn up in this little text editing thing. Now, it's really just the BASIC line editing facility in another incarnation, but it's a good trip. Like BASIC, it has the peculiar characteristic of using the system's RAM files. That is, if you "create" a file using the text editor, you are always updating it whenever you bring it to the screen. It never has to be saved, and can't be lost accidentally.

The editing functions are actually quite all right on this thing. You can move around, insert and delete. There is automatic line ending happening and you can search for strings. For those whose fingers are used to larger systems, let instinct rule and you'll discover that it supports the same cursor mover commands as Wordstar . . . how karmic. Sadly, you cannot edit BASIC text files with it . . . this would be a useful tool.

Using this little text editor, you can create a file called ADRS, which will feed the address handler. Yes, there's one of those too . . . well, it's more of a phone directory, and obviously uses the search function of the text editor. Boy, the stack must get big in there.

The idea is to store the names of all the people you know who have phones in this file and then call it when you want to dial up one of them. It's a bit tedious unless you have a big phone directory which you lose frequently. The computer is harder to lose if you keep its AC adapter plugged in at all times . . . simply walk around the room 'til you spot a plugpack and trace the wire.

The address function is useful when you get into the final internal widget of the system, the Telecom program. This little brute has its own built in modem. In fact, it has two versions of it, one direct connect and one acoustically coupled. The acoustic coupler that you can get for it is a scream . . . it consists of a DIN plug, two wires and a speaker and a microphone that clamp onto your receiver. You could build one yourself with a speaker, a crystal mike button and some rubber bands except that Radio Shack has used a non-standard DIN plug. (DIN, by the way, means German Industrial Standard . . . a bit of a paradox, this.).

The computer can behave like a less than moronic but not quite smart terminal. You can set the protocol . . . it defaults to the usual standard for bulletin boards, clever thing. You can also autodial. Yes, you can use the numbers in the address minder to dial the terminal. This can be for either voice or data. It's sort of a Bell Displayphone without the tube.

But Soft . . . But Why?

The TRS Model 100 is, without question, a highly neat toy. It has a powerful language, lots of options and plenty of I/O. However, it also has a price tag to really skewer your budget. $1100.00 will set you up with the makings of a pretty decent full sized system which may insist on having you write its address minder, but will at least have a tube.

As a straight computer, the TRS Model 100 offers about as much RAM as a VIC-20.

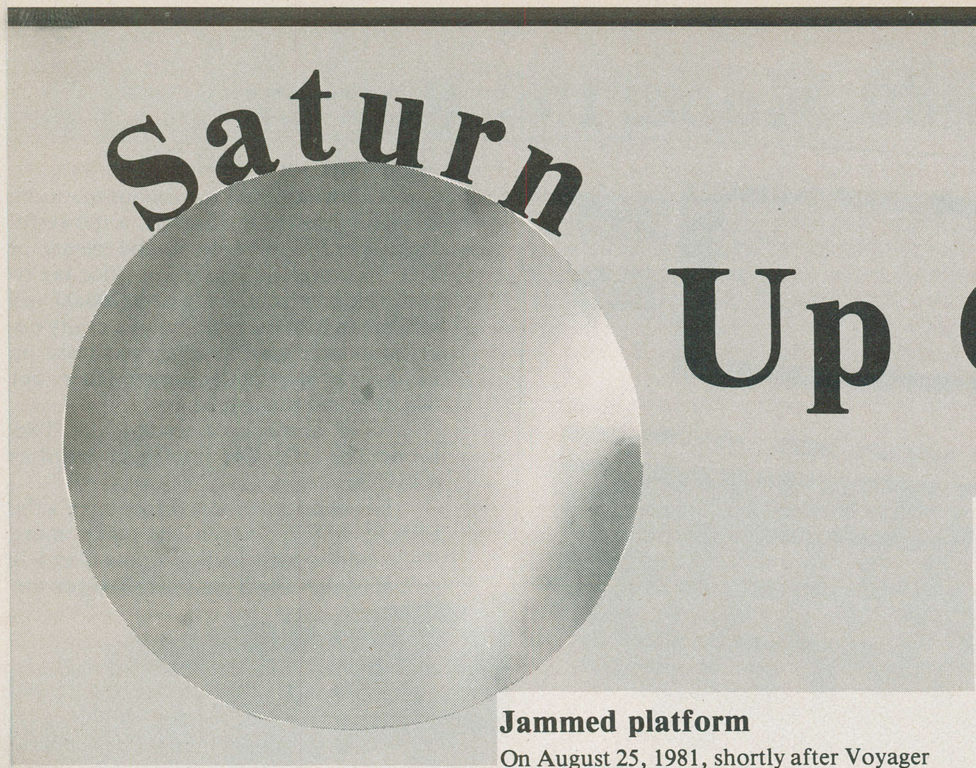
For about the same price, there's the EPSON MX-20, which has rather more RAM and a built in tiny printer, and is probably also worth considering if you are hot to have a computer that looks like a book.

While the Model 100 did everything it purported to do, and quite well, I doubt the cosmic validity of doing most of them. Aside from computing on airplanes, most of the useful functions it offers can be handled by other, more capable systems which forego the box's serious limitations gotten into for the sake of size and low battery consumption. In short, you give up a lot of power for the privilege of being able to walk around with it.

As an interesting diversion, the Model 100 is unquestionably a trip, and I'll confess that my point of view may be restricted by my economic circumstances. I require all diversions and foolishnesses costing over four hundred dollars to have tires and pistons.

But, arghh, Billy, ye could be takin' it out inta' the icy Nort' Atlantic t' compute the number o' fish we'd be takin'. ETI

Saturn Up Close



Voyager 1 passed within 126,000 km of Saturn in late 1980, giving us the closest view of the giant ringed planet we had ever seen. This flyby laid the groundwork for Voyager 2's 1981 encounter with the planet from only 101,000 km, considerably extending the information gathered on the planet to date.

IN LATE August/early September 1981 the Voyager 2 spacecraft swept by Saturn at a distance of 101,000 km above the tops of the clouds. The huge gravitational field of this planet swung the craft on towards its next planetary encounter with Uranus in January 1986. Late in 1980, Voyager 1 came within 126,000 km of Saturn's cloud tops, and the knowledge gained from this Voyager 1 encounter enabled us to plan the Voyager 2 mission for maximum data raturn.

Voyager 2 not only approached closer to Saturn, but it carried two somewhat better television cameras, one for narrow-angle or close-up work and the other for wide-angle work. Thus Voyager 2 was able to provide us with many high-resolution images not only of the surface of the planet itself, but also of its rings and its moons. One of the major discoveries of Voyager 1 was that the Saturnian ring system consists not merely of the few rings one can see from Earth, but that there were hundreds of them. The higher resolution provided by Voyager 2 cameras has shown that there are literally *thousands* of rings!

Jammed platform

On August 25, 1981, shortly after Voyager 2's closest approach to Saturn and while it was in the shadow of the planet and out of communication with the Earth, a moving platform in Voyager which carries the spacecraft's cameras became jammed. After the spacecraft emerged from behind the planet and resumed communications, commands were immediately sent to point the instruments on the platform away from the Sun to avoid possible damage from the Sun's radiation.

The platform carries two television cameras and two spectrometers (infrared and ultraviolet), apart from a photopolarimeter, which are mounted at the tip of a 2.25 m boom extending from the main body of the spacecraft. The platform can move in two directions, azimuth (or side-to-side) and elevation (up and down). The jamming affected only the azimuth movement.

Engineers first sent a command signal so that the complete craft rotated to point its delicate instruments away from the Sun. The problem of investigating the cause of the trouble was greatly magnified by the enormous distance through which the radio signal commands had to travel. A command signal took nearly 1½ hours to reach the craft and the effect of the command could not be received back on Earth for about another 1½ hours.

The jamming of the scan platform occurred about 45 minutes after Voyager 2 had passed through the ring plane of the planet, and this led to speculation that the

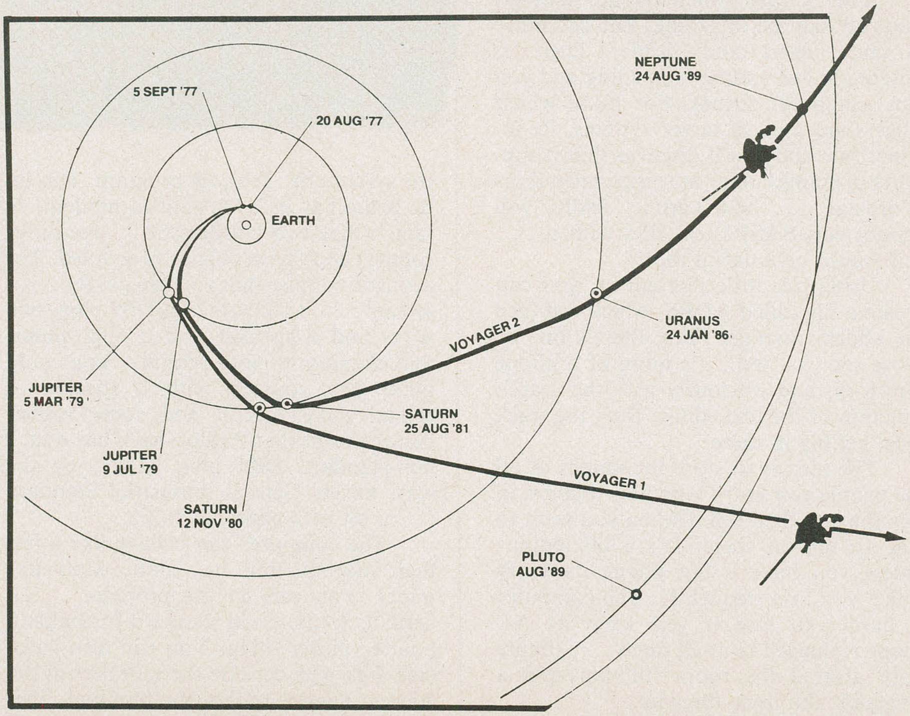


Fig. 1 The trajectories of Voyagers 1 and 2 and their encounters (courtesy of JPL).

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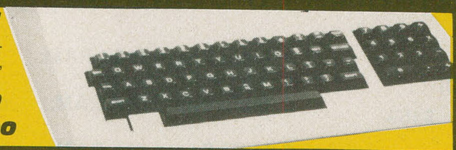

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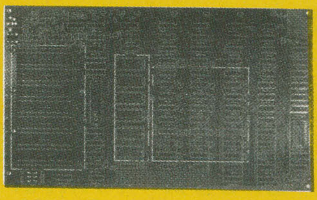

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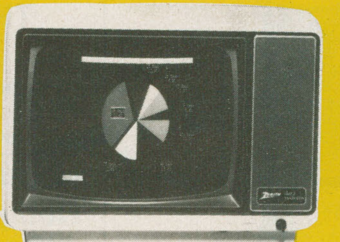

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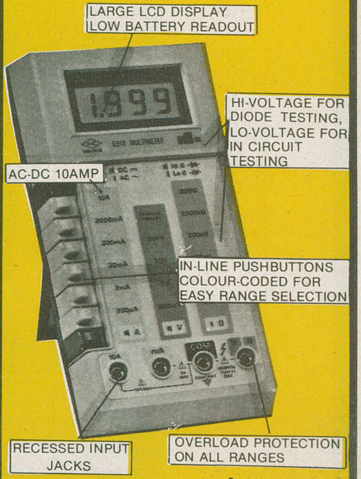

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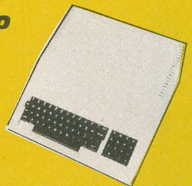

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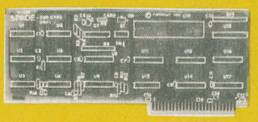

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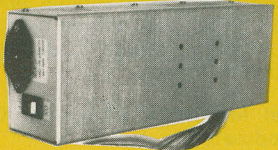

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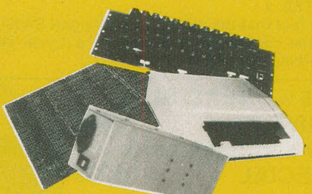

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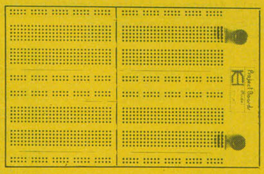

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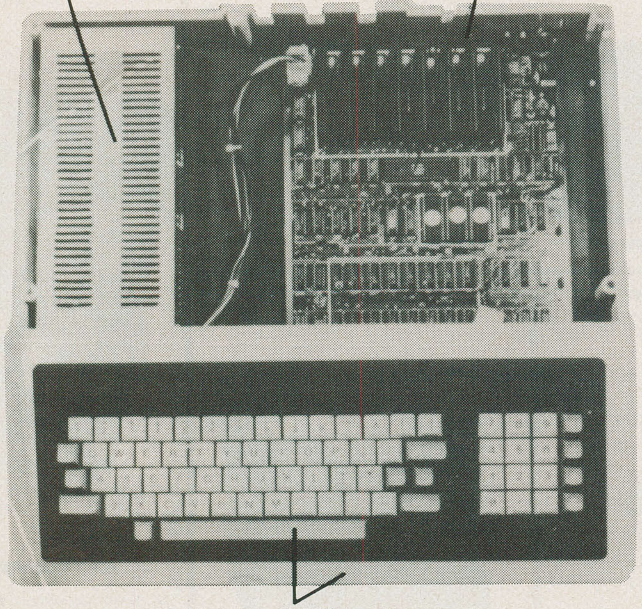

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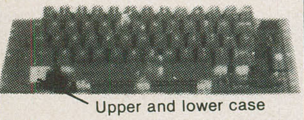

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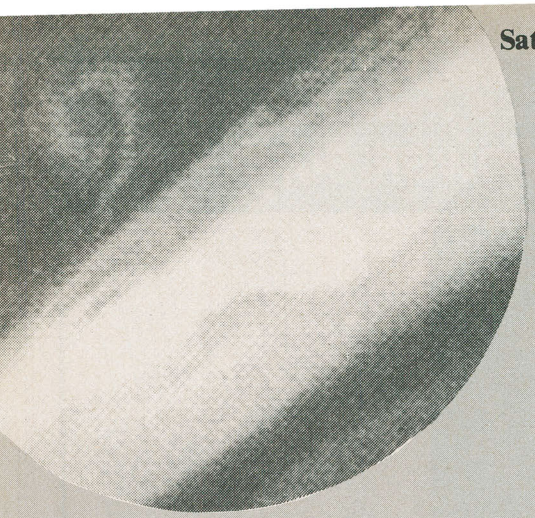


A Voyager 2 picture of Saturn's northern mid-latitudes showing a strangely curled cloud attached by a thin ribbon to the bright cloud region to the north (top of picture). The cloud has been monitored for seven rotations around the planet and it seems to be forming a closed loop. Other discrete clouds may be discerned to the east. Also evident is a ribbon-like structure in the white cloud region. Voyager 2 took this image on 16 August 1981 at a distance of 9.3 million km, when the smallest feature was about 90 km across.

problem was caused by the craft being bombarded with dust particles travelling at an enormous velocity relative to the craft.

However, on August 28, the platform was successfully moved in azimuth by command signals from the ground stations, which resulted in the instruments being pointed at Saturn once again. The response of the platform to azimuth commands has sometimes been hesitant and slow, but has steadily improved with use, and scientists are confident that satisfactory operation will be achieved at Uranus. In any case, the platform has been left in a useful position for the Uranus encounter in 1986, so good images should be returned even if the platform should again become jammed.

It is interesting to note that the identical platform aboard Voyager 1 jammed early in this craft's flight, but eventually worked itself free. The reason for the fault in Voyager 2 is not completely clear, but there is a firm opinion that the fault is probably not connected with the possible collision with the ring material. Indeed, the images returned before the craft reached the ring plane gave some indication that everything was not working quite as it should, and the spacecraft designers are wondering whether a small piece of plastic left in the gearbox assembly of the platform could have caused the fault on both craft.

Communications

Voyager 2 receives signals from Earth at a frequency of about 2113 MHz, the receiver being used either with a high-gain 3.7 m diameter parabolic reflector antenna or with a low-gain antenna. Voyager 2's primary receiver failed on April 5, 1978, and since then the craft has been operating with its back-up receiver. Both are phased-locked loop receivers able to lock onto and track a received signal over a 500 kHz bandwidth centred on the receiver's 'best-lock frequency' or BLF. A tracking loop bandwidth of at least 150 kHz is required to accommodate Doppler shift effects induced by the rotation of the Earth and by the acceleration of the spacecraft in the region of the planet. In addition to the failure of the primary receiver, the back-up receiver was found to have a shorted capacitor in its phase-locked loop filter, which reduced the tracking loop bandwidth from 500 kHz to 200 Hz. Special equipment was therefore used to keep the frequency received by the spacecraft constant to within about 50 Hz by altering the frequency transmitted from the ground station to the craft to compensate for the rotation of the Earth and for the acceleration of the craft.

Although the receiver operates only in the S-band, the spacecraft contains both S-band and X-band transmitters. The S-band transmitter is a solid state amplifier, but the other three transmitters use travelling wave tubes. The X-band transmitter uses only the high-gain antenna, but the S-band transmitter can use either antenna.

X-band signals from the craft can be received by both the 64 m diameter and 34 m diameter aerials of Deep Space Network stations, but the 26 m Earth stations work only with the S-band signals. The signals reaching the antennae are about 100 attowatts (10^{-16} W), so very low noise, low temperature amplifiers are required to detect it. An improvement of about 1 dB in the signal-to-noise ratio is obtained by suitably processing the signals received by a 64 m and 34 m diameter antenna at two of the three locations (Goldstone, Spain and Australia). This results in a signal being obtained which is equivalent to that which would be provided by a single 72 m diameter reflector at each location.

Loss of the signal from a 34 m station reduces the data rate or increases the error rate, but does not cause the loss of all the data. Loss of the 64 m signal causes loss of the X-band capability and reduces data to the engineering measurements only. The X-band signal is badly affected by bad weather (water vapour or rain) at the receiving station and data loss can be extensive on days when heavy rain or snow falls on the antennae. Critical data was therefore recorded on the spacecraft and re-transmitted twice over separate Earth station networks to provide protection against bad weather.

Clouds

Now that we have considered some of the engineering problems associated with the Voyager mission, let us look at some of the science results returned by Voyager 2.

Saturn has a very turbulent atmosphere in which the clouds are carried along by the winds at high speeds. The winds move fastest in the region of the equator, blowing eastwards at speeds up to some 1770 km per hour (about ten times as fast as a hurricane on the earth). Jupiter has global winds which move at about one-quarter of this speed.

Brown and white spots on the surface of the clouds are enormous regions of storms. One of these was seen by Voyager 1 some nine months earlier and was still raging as Voyager 2 passed by the planet; it is some 2500 km across. Cyclones and anti-cyclones occur on Saturn and rather resemble the corresponding wind formations in the atmosphere of the Earth. Unlike Voyager 1, Voyager 2 has found easterly winds at several latitudes.

Voyager 2's infrared spectrometer has made measurements on the upper parts of the Saturnian atmosphere which indicate that the temperatures some 40 km below the top of the planet's visible clouds vary from - 193°C to - 181°C, but the temperature patterns do not seem to correlate with the wind patterns as shown by the television images.

Saturn consists almost entirely hydrogen and helium and has a density of only about 0.7 g/cm^{-3}. Its equator bulges considerably owing to its rapid rate of rotation — some 10 hours 39 minutes — for such a huge body.

The rings

Saturn's rings — some 270,000 km across — are one of the best-known things one can see in a telescope, although they are very thin (about 2 km). They consist of large numbers of ice and rock lumps all independently orbiting the planet like tiny moons. The largest of the ring particles weighs many tons, but most are far smaller.

The smallest microscopic fragments in the rings are elevated out of the ring plane by the gravity fields of the planet to form the 'spokes' which were seen by Voyager 1 across the bright ring.

Voyager's photopolarimeter was pointed through the rings at the star Delta Scorpii, which is some 989 light years distant. Measurements of the light from this star as it passed through the ring materials provided high-resolution data on the number of ringlets, their densities and widths and the widths of the gaps between them. This technique enabled structures

of a size down to some hundreds of metres to be observed, whereas the optimum resolution of the Voyager imaging system is seldom better than 10 km. This high resolution could be obtained owing to the small apparent size of the star and the high resolution of the instrument on Voyager 2.

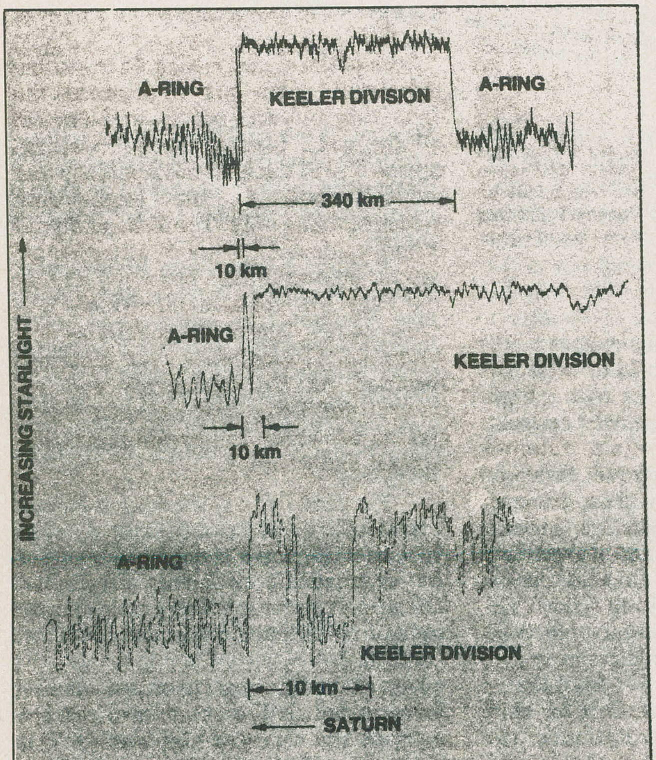
Radio science experiments investigated the effect of the rings on the radio waves emitted from Voyager 2 at both S-band and X-band frequencies; some measurements of the effect of Saturn's atmosphere on radio signals passing through some of the upper layers also provided valuable information (the radio signals will not pass through the bulk of the atmosphere). The interaction of the radio signals with the rings enabled some estimation to be made of the sizes of the particles of the rings. The sizes of these particles varied from one ring to another, but generally the large particles in the rings were fairly evenly spread through the ring, while smaller particles (of diameter less than about 10 cm) tended to collect at the edges of the rings.

There has been much speculation about the mechanical stability of the rings of Saturn and several theories have been tested against Voyager 2 observations. A mechanism is needed to hold the ring particles in orbit or they would have escaped into space long ago. One theory suggests the ring particles resonate in some way with one of the larger satellites, and some of the larger gaps in the rings do occur at orbital resonances with Mimas (for example, some particles make two orbits for every one orbit of Mimas). Another theory suggests that minor moons herd each ringlet, but Voyager 2's cameras could find no evidence for such minor moons other than those already known to shepherd the F ring. Voyager 2 found some evidence to support a third theory of density waves in the ring particles. Yet another theory involves collisions between the particles of the rings; hard objects would rebound from the impacts, but softer ice may shatter.

Voyager 2 gave considerable attention to the mysterious spokes in the B ring and used time-lapse photography, within minutes, mainly near the point where the ring particles emerge from the shadow of Saturn. Most of the spokes disappear before completing a single orbit of the planet, but new spokes can form on top of the remains of earlier ones. The spokes are formed on both faces of the rings (illuminated and unilluminated) and extend outwards from the planet like the spokes of a wagon wheel.

It has been suggested that the spokes are electrostatically levitated particles of fine dust which have been raised above the plane of the remainder of the B ring by the magnetic field of the region. Three images were taken during the ring plane crossing at a time when the rings could be viewed nearly edge-on in an attempt to see this fine dust. However, no evidence of particle levitation could be seen in any of these images — not even in a particularly impressive image taken only 0.5 degrees above the ring plane.

During the crossing of the ring plane, the plasma wave radio receiver showed an enormous increase in the intensity of its signal, and the plasma wave investigators believed this was due to the ionisation of minute dust particles striking the spacecraft, although these dust particles are understood to have been too small to damage Voyager 2 in any way.



The high resolution of Voyager 2's photopolarimeter revealed ringlets that are undetectable by the cameras or radio systems. These three plots show increasing resolution of an area including the Keeler (Encke) Division and the edges of the A-Ring. The amount of starlight (from the distant star Delta Scorpii) passing through the rings is plotted as a single line of varying brightness. Peaks in the curve indicate areas where there is little material to block the passage of starlight, while dips in the curve indicate areas where starlight is blocked by material. The Keeler Division is a relatively empty gap and is therefore seen as a peak in the top plot. The dip in the Keeler Division is probably the 'kinky' ringlet photographed by Voyager 2's camera. With increasing resolution (moving down from the top plot), a feature at the inner boundary between the A-Ring and Keeler Division becomes apparent. This feature is believed to be a ringlet.

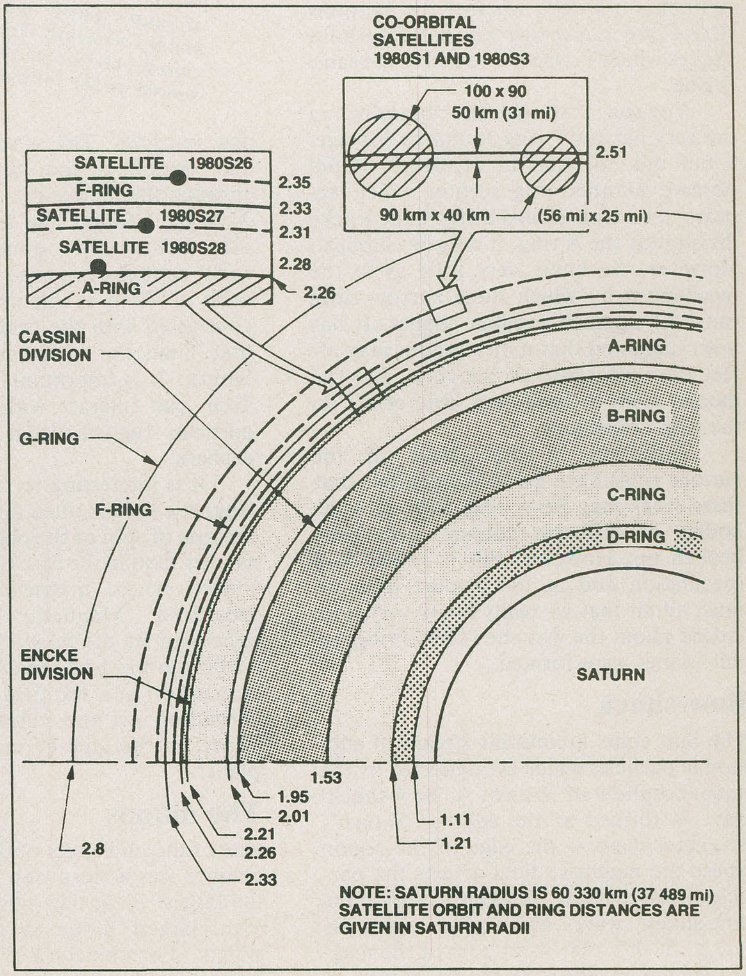
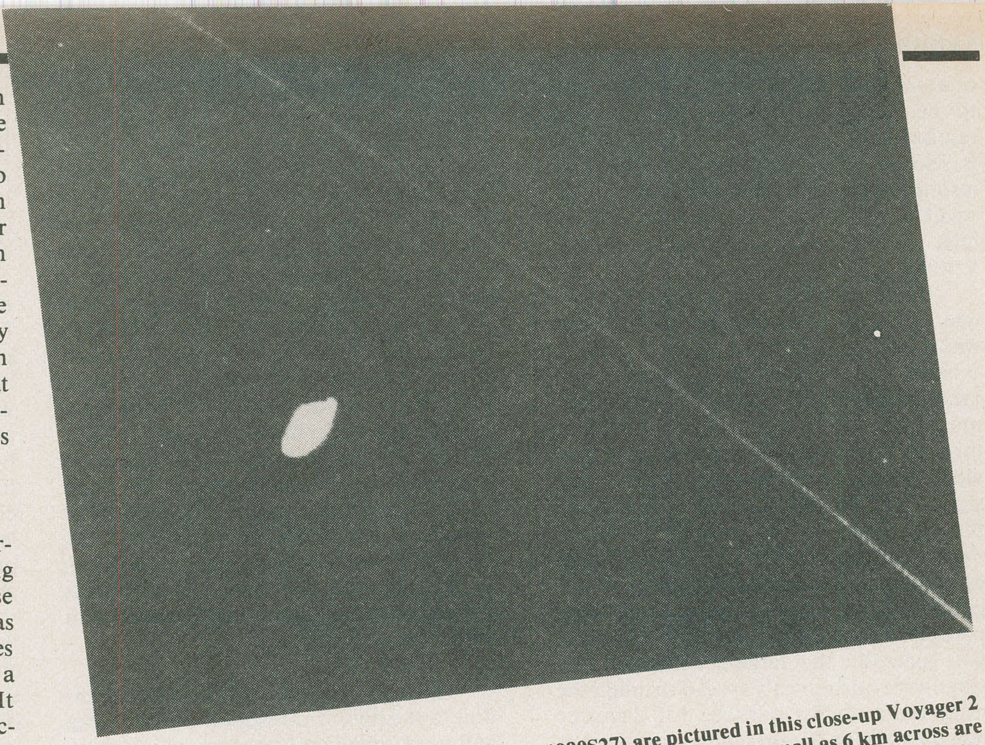


Fig. 2 Saturn's rings were given letters in the order of their discovery, but the rings seem to be affected by small satellites in ways not yet fully understood (courtesy JPL).



Saturn's ring and its inner shepherding satellite (1980S27) are pictured in this close-up Voyager 2 image acquired 25 August 1981 from a range of 365 000 km. Features as small as 6 km across are visible. The satellite is elongated and irregular, with its longest axis pointing towards the centre of Saturn (upper right here). As seen here, the F-ring is thin and does not show the multiple braided structure Voyage 1 saw, nor is there any indication of a band or kink in the ring at its closest point in the shepherd; such a feature would be consistent with some of the theories advanced on the formation of the braids.

It is interesting to note that a gap in the outer edge of the A ring, known as the Encke Division (after Johann Franz Encke of the Berlin Observatory, who reported seeing a shading in the A ring in 1837), is likely to be renamed the Keeler Division, since the Working Group on Planetary System Nomenclature of the International Astronomical Union believe James E. Keeler of the Lick Observatory saw this division about 1888 with a 90 cm refractor telescope, whereas it is felt that Encke, using a 22 cm telescope, was probably seeing another feature and not this small gap.

Lightning

A particularly interesting discovery occurred when Voyager found lightning discharges occuring in the B ring; these discharges were roughly 10,000 times as powerful as the typical lightning flashes which occur on Earth, each having a power approaching 1000 megawatts. It has been suggested that the lightning occurs when a small moon of Saturn interacts with the ring particles and generates a very strong electric field, but no such moon has yet been observed. Neither is it known whether the lightning strokes are in any way associated with the spokes which Voyager 1 found in the same B ring.

Voyager 2 sought the 'braiding' in the very narrow F ring found by Voyager 1 but did not find it. However, it did observe another ring section which appears to be kinked, this being in the Encke division by the A ring; it may be elliptical. However, we know very little as to the mechanism by which these narrow rings can take up such peculiar shapes. It has been suggested that minor moons may affect the uniformity of the rings, but the moons seem to have very little effect on the ring uniformity.

Variations in the colour of the various rings have led to suggestions that these rings may have been formed when bodies of different colours have been broken up. However, this is rather wild speculation and at the present time we must admit that we really know very little indeed about the way the famous rings of this planet were formed.

Bow-shock

The Sun emits a constant stream of subatomic particles which are deflected by the magnetosphere of Saturn. A 'bow-shock' wave is formed at the edge of Saturn's magnetosphere — the edge of the region where the magnetic field affects the particles from the Sun. Voyager 2 crossed the bow-shock wave about five times as 'gusts' in the solar wind pushed the magnetosphere in and out of the region in which Voyager 2 was traveling.

The spacecraft had already detected a region in the solar wind where there were few particles. The scientists believe that this region is due to Jupiter moving through the solar wind. Nearer to Saturn, Voyager 2 found that the magnetosphere extended to only some 18.6 Saturnian radii, so it did not even extend out to the orbit of Titan at this point. This may be contrasted with the finding of Voyager 1 that Titan lies in the magnetosphere of Saturn. It is important to know whether Titan can interact with the high-energy particles trapped within Saturn's magnetosphere.

It is interesting to note that Saturn's magnetic field is tilted only about 1° from the axis of spin of the planet. This is much smaller than in the case of any of the other planets whose magnetic field has been measured. Magnetic fields may be generated by the flow of electric currents within certain parts of a planet, so an investigation into the field may provide information on the current flowing and hence on the type of material inside the planet.

The moons

One of the objectives of the Voyager 1 encounter was a close view of Titan, by far the largest Saturnian satellite and the second largest moon in the whole solar system. Fortunately Voyager 1 obtained good images of Titan or Voyager 2 would have been re-programmed to accomplish this and would have been unable to continue for encounters with Uranus and Neptune. Voyager 2's encounter with the Saturnian system was therefore mainly determined by the requirement to place it on its desired trajectory to the outermost planets.

Voyager 2 came closer to Enceladus, Tethys, Hyperion, Iapetus and Phoebe than Voyager 1, so images with better resolution could be obtained. Fortunately it returned some excellent images of some of these moons before the platform jammed, but this fault resulted in about two-thirds of the close-up images of Enceladus being lost.

The first flyby of a major moon occurred as Voyager 2 passed Iapetus, which is heavily cratered and has a surface which probably dates back to the early days of the solar system. Strangely enough, this moon has dark and bright sides, and the composition of the dark side (reflectivity about 5%) has created much speculation; it seems too dark to be a silicate and is comparable with the dark material in asteroids which contain much carbon. The density of Iapetus is relatively low, so it cannot all consist of a normal type of rock.

Voyager 2 next passed Hyperion, whose diameter is little more than one-fifth of that of Iapetus, but this strange moon is elongated, with axes some 210 km and 350 km long, and appears to be heavily cratered. Scientists would have expected its long axis to have pointed towards Saturn because of the gravita-

tional effect of the planet, but they have calculated that if it was knocked from this position it would take a time similar to the age of the solar system to return, since it is so far from Saturn that the gravitational field of the planet is relatively small at that distance.

Titan

Voyager 2 passed by Titan at a distance of more than a hundred times that of Voyager 1, so image resolution was greatly inferior to the Voyager 1 observations. However, the images returned were adequate to show that changes had occurred in the atmosphere of the largest of Saturn's moons since the visit of Voyager 1. The photopolarimeter on board Voyager 2 looked for the particles in the atmosphere which scatter light polarised by the scattering process. The colour of the scattered light is related to the size of the particles, since smaller particles scatter light of higher frequency (like the particles which scatter the light in the upper atmosphere of the Earth to produce a blue sky, whereas larger smoke particles can scatter the red light of longer wavelength).

One may well ask why this measurement was not made by Voyager 1 from a much shorter distance, but the answer is that the identical photopolarimeter on Voyager 1 failed. The particles in the atmosphere of Titan were found to scatter radiation from the ultraviolet and red wavelengths; calculations indicate that their dimensions are of the order of 0.1 um, but there is some evidence that these particles may not be spherical — perhaps crystals, who knows?

Voyager 2 passed minor planets and also Dione and Mimas, but at much greater distances than did Voyager 1. Only about 20 minutes after its closest approach to Saturn, Voyager 2 passed by Enceladus, which lies in the diffuse outermost E ring. The surface of this moon is relatively young and fairly smooth. Some parts of the surface displayed no craters detectable by Voyager 2, and these parts are probably less than 10^8 years old — very young in terms of the age of the solar system. Is Enceladus volcanically active? Its surface seems to suggest that it may show some such activity, but probably not so much as that of the Earth and certainly far less than Jupiter's moon Io — the most volcanically active object found in the solar system.

The surface of Enceladus resembles that of the far larger Ganymede, a moon of Jupiter. Voyager 2 returned an image of Enceladus in which not only the part illuminated by the sun could be seen, but also the remainder of the moon in the light reflected from Saturn. This 'Saturnshine' effect is similar to the 'moonshine' (also known as the 'new moon in the old moon's arms') which we see on earth at a time shortly after new moon, when the light reflected from the Earth weakly illuminates the part of the moon not directly illuminated by the sun.

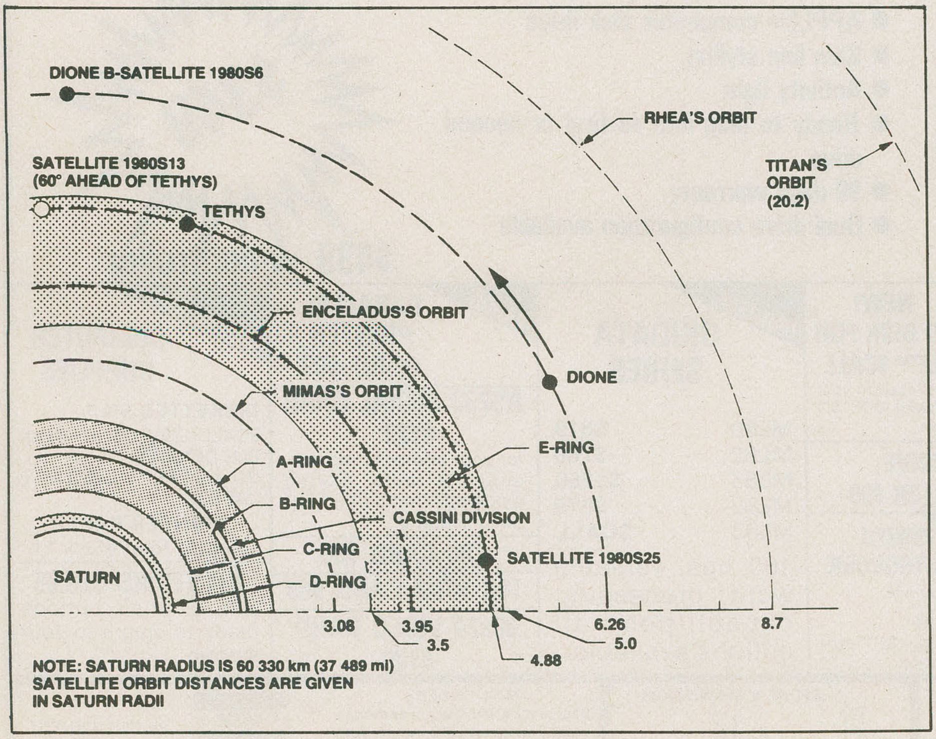


Fig. 3 Orbit locations of Saturn's moons relative to the ring system (courtest of JPL).

Tethys

Good images of Tethys, one of the major moons of Saturn, were obtained by Voyager 1, but Voyager 2 not only approached the moon about five times closer, but also approached from a different angle. This enabled it to see the largest crater yet found in any of Saturn's moons, with a diameter of some 400 km. It is thought to be a very old crater, even older than the large valley found by Voyager 1 on the other side of Tethys (which was also seen by Voyager 2). It has been concluded that the crater has been flattened by the flow of softer ice and it no longer shows the deep bowl-shape characteristics of fresh craters in hard ice or rock. It was probably formed when Tethys was much warmer than it is at present.

Tethys shows two distinct types of terrain. One of these is bright with densely cratered regions, while the other is relatively dark with lightly cratered plains that extend in a broad belt across the satellite. The latter plains are thought to have been formed after the initial cratering process by internal movements in the moon.

Voyager 2 received some unusual 'pinging' radio signals from the moons Tethys and Dione or from regions near to these moons, some 300,000 to 380,000 km above the cloud tops of Saturn. Scientists have speculated that these signals may arise from a cloud containing ions of hydrogen, carbon, oxygen, etc., which may come from atoms emitted by the moons.

Conclusions

In spite of the problem with the jamming of the instrument platform, the Voyager 2 mission has undoubtedly been an outstanding success, with virtually all its objectives accomplished. This is yet another magnificent achievement of a large team of workers in a project which is so complex that it is difficult to imagine all the details. One should not forget that for 1½ hours all the observations on the night side of the planet had to be recorded on magnetic tape for subsequent transmission to Earth.

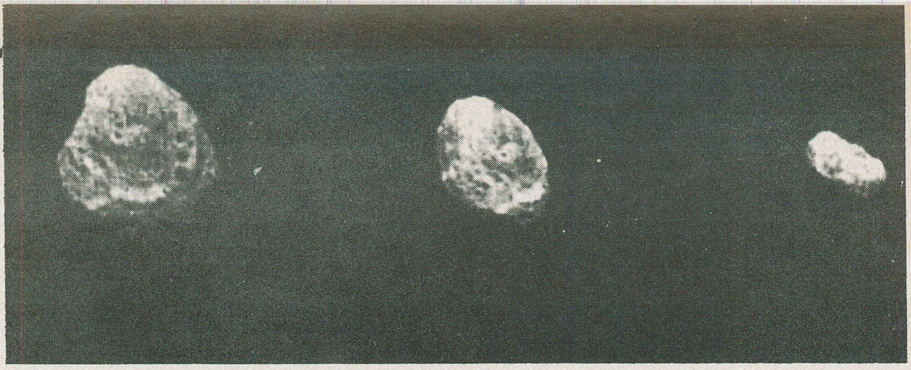
Voyager 1 is now moving out of the solar system with all its encounter missions accomplished, but it is searching for new evidence of the limits of the solar wind. Voyager 2 has been swung by Saturn's enormous gravitational field toward its next encounter with Uranus in 1986 and, hopefully, a Neptune encounter in 1989. There is no possibility of it going near Pluto.

In view of the failure of the main receiver on Voyager 2 and the fault on the back-up receiver, one may well ask what the position would be if the back-up receiver finally failed completely before

the Uranus encounter. The onboard computer would then provide the command signals to guide the spacecraft to Uranus and to make a number of measurements there. Such is the power of modern electronics!

Acknowledgements

The writer is greatly indebted to Don Bane and to Frank Bristow of the Public Information Office, Jet Propulsion Laboratory, Californian Institute of Technology, for providing excellent photographs and information on the Voyager missions. Acknowledgement is also made to Ms. Kit Weinrichter, formerly of NASA's Ames Research Center, California, for much general help over an extended period, especially as regards communications with California.



These three views of Hyperion were obtained as Voyager 2 flew by this satellite of Saturn. They were taken (starting at the top) the morning of 23 August 1981 from a range of 1.2 million km, the morning of 24 August from 700,000 km, and at noon on 24 August from 500,000 km. Together they show the changing aspect of the satellite as Voyager moved in for closer views. Hyperion, roughly 360 km by 210 km and shaped like a hamburger, is probably not in a gravitationally stable position. Its surface is pock-marked with many meteorite-impact craters. It is possible that one of these impacts jostled Hyperion out of position and that the satellite will swing back gradually.

SATURN'S SATELLITES

Name	Diameter	Distance	Closest Approach Voyager-1	Voyager-2
1. 1980S28	40x20 km (25x12 mi)	137 670 km (85 540 mi)	219 000 km (136 000 mi)	287 170 km (178 300 mi)
2. 1980S27	220 km (140 mi)	139 353 km (86 590 mi)	300 000 km (186 000 mi)	246 590 km (153 220 mi)
3. 1980S26	200 km (120 mi)	141 700 km (88 050 mi)	270 000 km (168 000 mi)	107 000 km (66 490 mi)
4. 1980S3	90x40 km (55x25 mi)	151 422 km (94 089 mi)	121 000 km (75 000 mi)	147 010 km (91 350 mi)
5. 1980S1	100x90 km (60x55 mi)	151 472 km (94 120 mi)	297 000 km (185 000 mi)	222 760 km (138 420 mi)
6. Mimas	390 km (242 mi)	185 600 km (115 300 mi)	88 440 km (55 000 mi)	309 990 km (192 600 mi)
7. Enceladus	500 km (310 mi)	238 100 km (147 900 mi)	202 040 km (125 500 mi)	87 140 km (54 100 mi)
8. Tethys	1050 km (652 mi)	294 700 km (183 100 mi)	415 670 km (258 300 mi)	93 000 km (57 800 mi)
9. 1980S25	30-40 km (19-25 mi)	294 700 km (183 100 mi)	237 332 km (147 471 mi)	284 396 km (176 715 mi)
10. 1980S13	30-40 km (19-25 mi)	294 700 km (183 100 mi)	432 295 km (268 616 mi)	153 518 km (95 392 mi)
11. 1980S6	160 km (100 mi)	378 060 km (234 920 mi)	230 000 km (143 000 mi)	318 200 km (197 720 mi)
12. Dione	1120 km (696 mi)	377 500 km (234 600 mi)	161 520 km (100 400 mi)	502 250 km (312 000 mi)
13. Rhea	1530 km (951 mi)	527 200 km (327 600 mi)	73 980 km (46 000 mi)	645 280 km (401 000 mi)
14. Titan	5140 km (3194 mi)	1 221 600 km (759 100 mi)	6490 km (4033 mi)	665 960 km (413 800 mi)
15. Hyperion	290 km (180 mi)	1 483 000 km (921 000 mi)	880 440 km (547 100 mi)	470 840 km (292 600 mi)
16. Iapetus	1440 km (895 mi)	3 560 100 km (2 212 100 mi)	2 470 000 km (1 534 900 mi)	909 070 km (564 900 mi)
17. Phoebe	160 km (99 mi)	12 950 000 km (8 047 000 mi)	13 537 000 km (8 411 500 mi)	1 473 000 km (915 300 mi)

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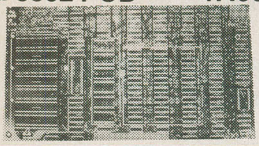

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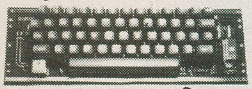

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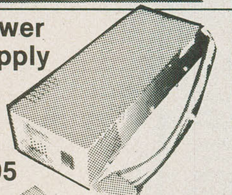

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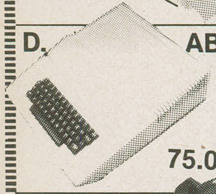

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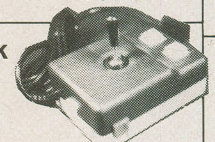

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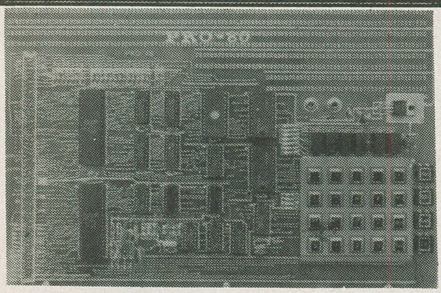

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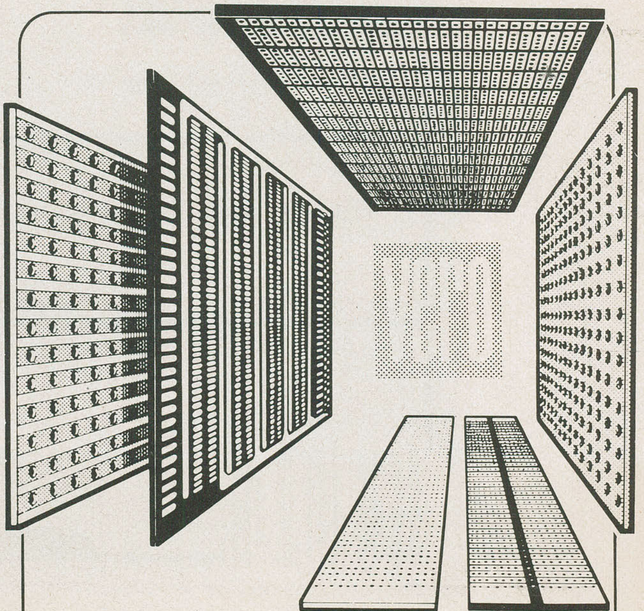

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OVERLOAD INDICATOR

PROJECT

A simple, accurate circuit that lets you know if your equipment is producing clipping distortion. By Bill Markwick.

ANY AMPLIFIER can only deliver so much signal; if you ask it for more, the output stage will neatly clip off what it can't produce. This clipping distortion is particularly abrasive to the ears. You may say that the answer is to turn down the volume, but other factors enter the picture. In a stereo, clipping distortion may be caused by various stages. The LED of the Indicator lets you pinpoint the culprit. In an audio mixer, the multiple sources make it difficult to determine which one is causing overload. Again, the LED to the rescue. Finally, in multi-amplifier PA setups, one or more amps may be clipping due to misadjusted levels, and the indicator reduces the panic.

This unit has the advantages of low cost, full-wave detection, very flexible supply voltage requirements, ease of installation, and a "pulse-stretcher" to hold the LED on long enough to catch the eye, even on short transients. The high input impedance means that you can add it to almost any point in the audio chain without causing distortion.

The wide supply range means that the Indicator will work from any dual supply from ±3V to ±15V, or any single supply from +6V to +30V. A single zener diode can be added to adapt the supply to most power amplifiers. The brightness of the LED will vary with supply voltage, and Table 2 shows the series resistor which will keep the LED current at about 15 mA for various voltages.

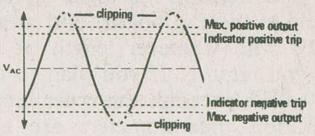


Fig. 1 Illustrating clipping of a sine wave by output overload.

Specifications

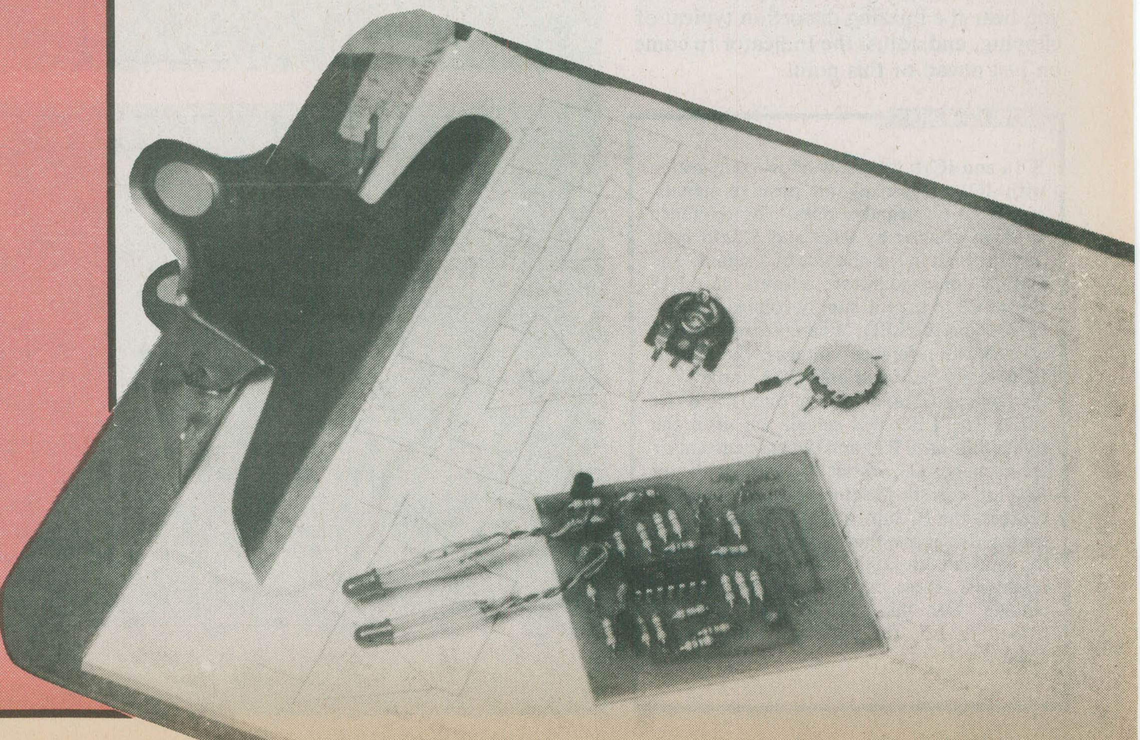
Triggering Level: (±15 V supply): ±10.8 V peak, 7.6 Vrms Frequency Response: 1.6 Hz to 150 kHz for 1 dB accuracy Supply Current: 1.2 mA (idle), 15 mA (one LED on), 30 mA (both on) Input Impedance: 200 K ohms.

TABLE 1 — ZENER DIODE SELECTION

+ Power Amp Supply Volts	ZENER
25	None
30	None
35	4V7 400 mW
40	10V 1W
50	20V 1W
60	30V 1W

TABLE 2 — LED RESISTOR (R19,20)

Single	Split	
6	± 3	300
12	± 6	750
18	± 9	1K2
24	± 12	1K8
30	± 15	2K2



Construction is straightforward. Assemble the PC board, and attach the LED's with whatever length of twisted wire you require. If you plan to use the unit with a preamp, the zener diode and calibration potentiometers are not required; just connect the unit according to the diagram for the type of power supply you have.

If you're installing it in a power amplifier, you'll probably need to fit the zener diode listed in Table 1. This keeps the applied voltage to 30 volts, well within the limit of the LM339; however, this means that the unit will require calibrating via the PC-mounted trim pots. Note that the PC is laid out to accept both Philips 411 series and the plastic Radio Shack series.

No calibration is necessary when used with a preamp. Just connect it ahead of the volume control as shown, or if there isn't one, to the final output. The LED will then light if the output approaches the clipping level of most amplifiers, and will be kept on for about two-tenths of a second by the pulse stretcher. If you'd like a little extra headroom, the unit can be made 3 dB more sensitive by decreasing R3 to 22K.

Calibrating the unit when used with a power amplifier is best done with an oscilloscope. If you have a speaker switch, turn them off and apply a signal, either sine wave or program, and monitor the output with the scope until you see clipping begin. Reduce the level slightly and adjust the Indicator to come on at this point. Some trial and error may be necessary if you use program material instead of a sine wave.

If you have no oscilloscope, you could try listening on headphones until you hear the buzzing distortion typical of clipping, and adjust the Indicator to come on just ahead of this point.

HOW IT WORKS

IC1a and IC1b form a window comparator with IC1a triggering on positive signals, and IC1b on negative ones. The reference voltages applied by R1,3 and 5 hold both outputs high in the absence of a signal. The LM339 open-collector outputs let R15 charge C3 to the full supply voltage, cutting off Q1 and the LED. When the input signal exceeds the reference voltages, the related IC changes state and pulls R13 to the V−, discharging C3 and turning on Q1 and the LED. The LED will remain on after the signal falls until R15 and the base current of Q1 recharge C3, about 200 mS. R13 and R17 are current-limiting resistors, and R7 protects the IC inputs if the signal voltage should rise above the supply rails. R19 sets the current through the LED, and the brightness then depends on the supply voltage. For this reason, R19 must be chosen to suit the available voltage; see Table 2.

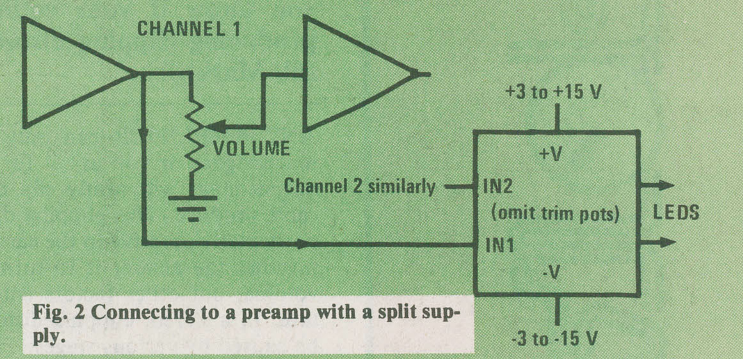


Fig. 2 Connecting to a preamp with a split supply.

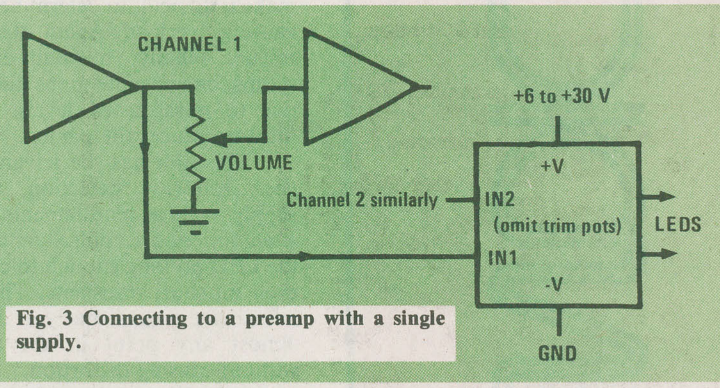


Fig. 3 Connecting to a preamp with a single supply.

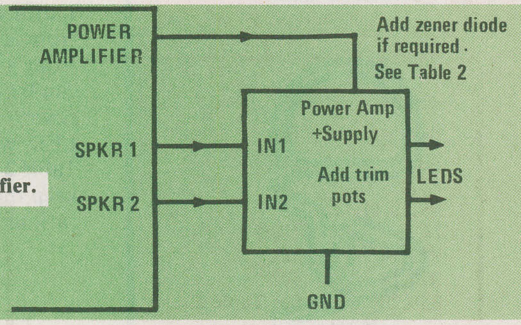
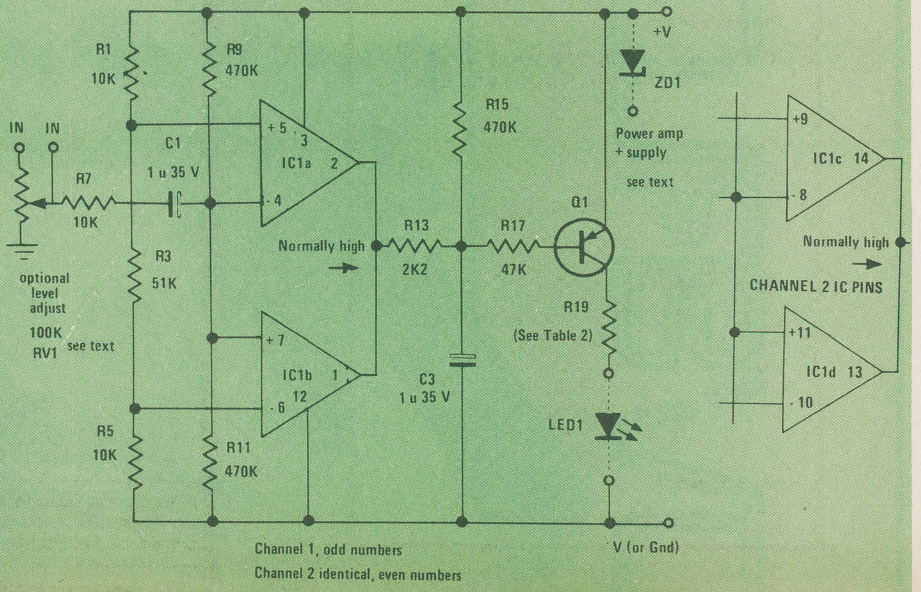
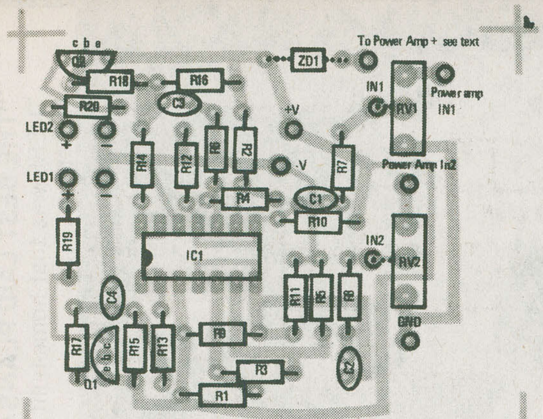
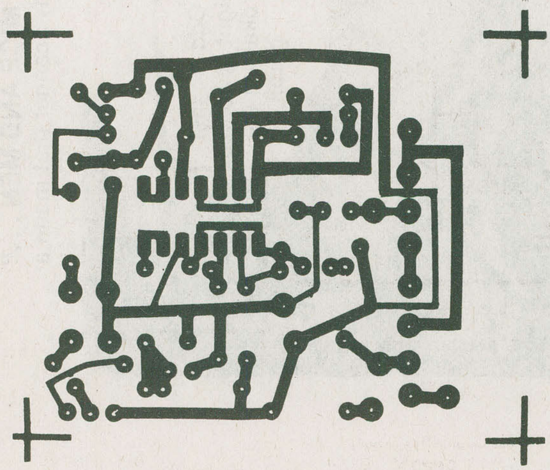


Fig. 4 Connecting to a power amplifier.







PARTS LIST

Resistors, (all ¼W, 5%)

R1,2,5,6	10K
R3,4	51K
R7,8	10K
R9,10,11,12, 15,16	470K
R13,14	2k2
R17,18	47K
R19,20	See Table 2

Potentiometers

RV1,2	100K trim pot, Philips 411-02261 or Radio Shack 271-220

Capacitors

C1,2,3,4	1u 35V tantalum

Semiconductors

Q1,2	2N3905 or any general purpose PNP
ZD1	See Table 1
LED1,2	any red LED
IC1	LM339 quad comparator

Miscellaneous

PC board, terminal pins, hookup wire.

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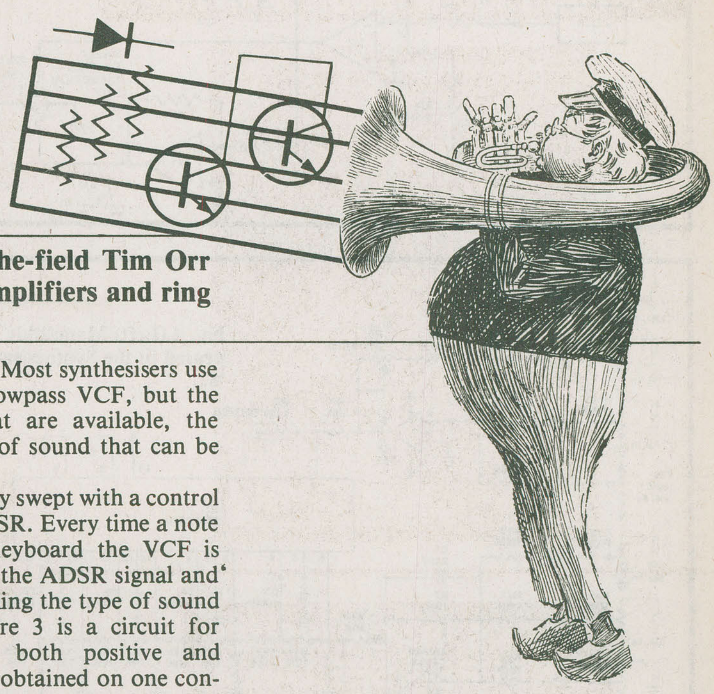


The second in this design series by leading-expert-in-the-field Tim Orr features voltage controlled filters, voltage controlled amplifiers and ring modulators.

THE FIRST group of circuits we consider this month are voltage-controlled filters. Figure 1 shows the circuit for a state variable filter with four frequency responses; lowpass, highpass, bandpass and notch. All four responses can be controlled by varying the gain of the two integrators. The Q factor of the filter can also be voltage controlled. If the Q is set to maximum, by turning off the feedback CA3080, then the circuit will become a sine wave oscillator (because the damping has been reduced to zero). Prior to this, very high Q factors can be obtained, of the order of 400. The frequency responses are shown in Fig. 2. Most synthesisers use a −24 dB/octave lowpass VCF, but the more responses that are available, the wider is the choice of sound that can be preduced.

VCFs are usually swept with a control voltage from an ADSR. Every time a note is played on the keyboard the VCF is swept, the shape of the ADSR signal and' its polarity determining the type of sound that is heard. Figure 3 is a circuit for sweeping a VCF. both positive and negative sweeps are obtained on one control pot. Figure 4 shows a VCF chip, the SSM 2040 which was covered in the November, 1982 issue of ETI.

Another CA3080 VCF is shown in Fig. 5. Note that the accuracy of the exponentiator need not be as good as that needed for a VCO (unless you are going to make the VCF oscillate and track a VCO). A somewhat different VCF is shown in Figs. 6 and 7. The bi-quadratic filter has a Q factor that is proportional to the cut-off frequency. So, as this frequency is increased, the Q factor will increase. This gives a constant ringing time which is independent of frequency. All the previous VCFs have a constant Q operation.

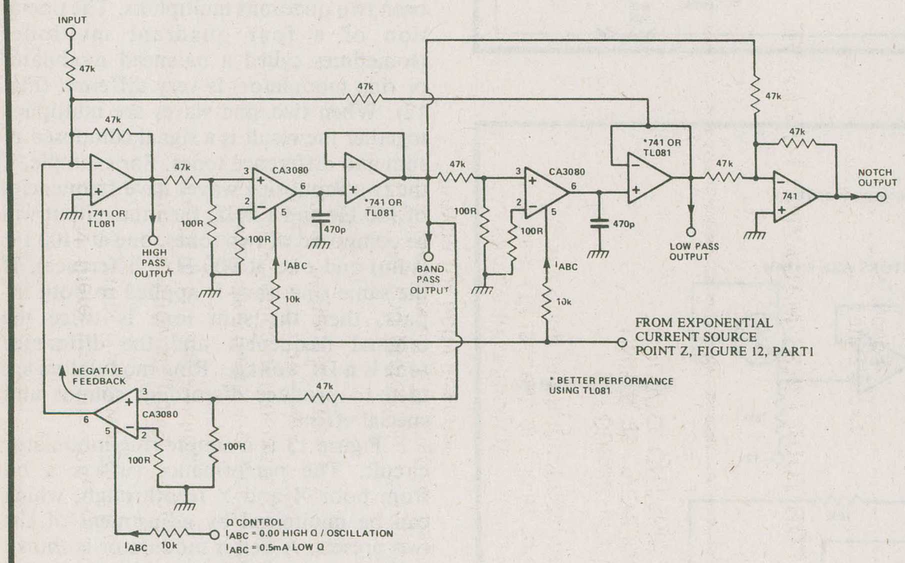


Fig. 1 State variable VCF.

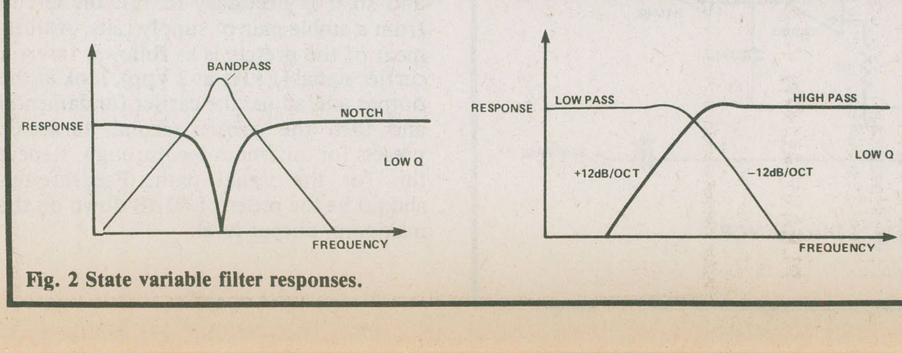


Fig. 2 State variable filter responses.

VCA And Ring Modulators

Voltage controlled amplifiers are one of the easier synthesiser building blocks to make, as long as you don't want low noise and low distortion operation. Figure 8 shows a standard linear VCA. The audio input is attenuated to about 40 mVpp and then fed into the CA3080, the gain of which is controlled by the I_{ABC} current. If the audio input is removed, control breakthrough will probably be seen at the output. Most of this is caused by the input offset voltage of the CA3080 being multiplied by the I_{ABC} control current. The offset can be nulled out by adding a small DC voltage to the non-inverting terminal, which should eliminate most of the control breakthrough. Any residual breakthrough is due to current mirror mismatches in the CA3080 and is unavoidable. Distortion may also be rather high, perhaps in the region of

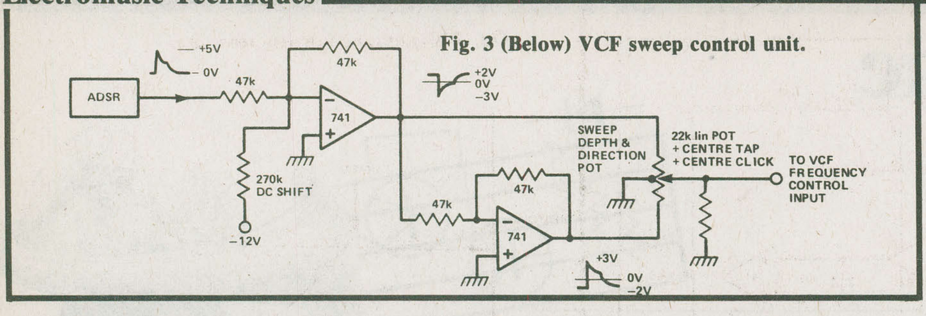


Fig. 3 (Below) VCF sweep control unit.

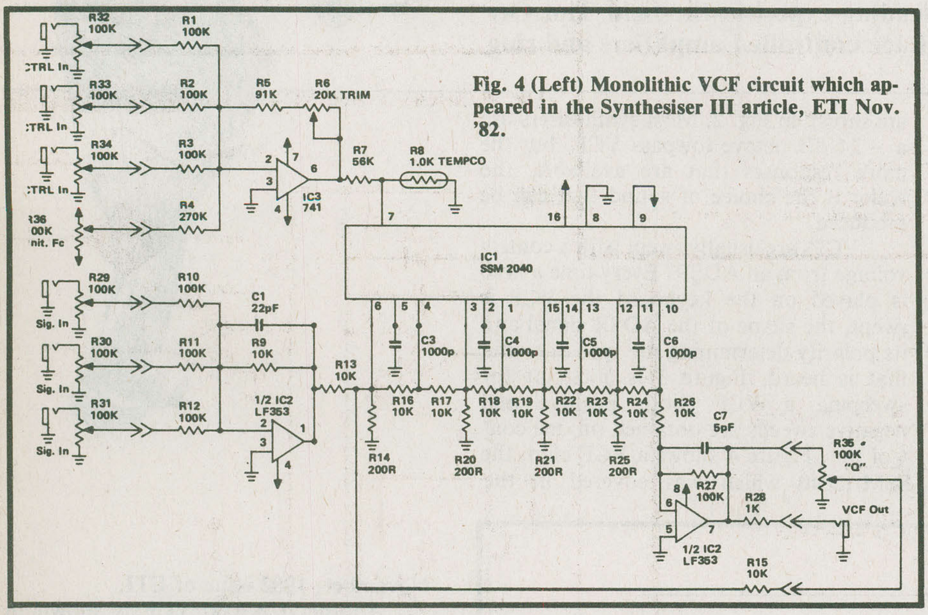


Fig. 4 (Left) Monolithic VCF circuit which appeared in the Synthesiser III article, ETI Nov. '82.

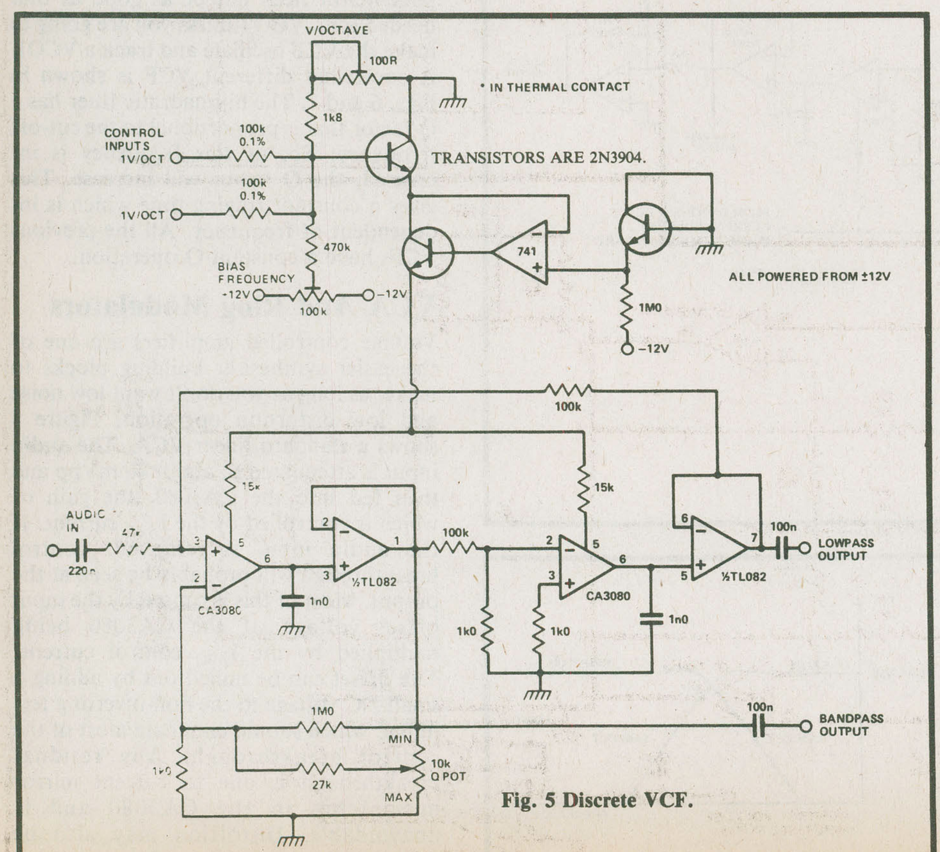


Fig. 5 Discrete VCF.

0.5%, but this is not generally considered to be a problem in synthesiser circuits. Lowering the input signal level will reduce the distortion at the expense of an increase in the noise level.

A better VCA is shown in Figure 9. This is the 1537A monolithic VCA, and can be configured for either stereo or mono. A complete article covering applications of this chip appeared in the June, '81 issue of ETI. A third VCA is shown in Fig. 10, this one being constructed from a CA3046 transistor array. It uses two of the transistors as a predistortion circuit so that a higher operating signal level can be used for the same level of distortion. In fact, the predistortion principle is used in several multiplier chips, including the LM13600 which is used in the next circuit, (Fig. 11). The two LM13600 circuits are used as low distortion VCAs. A predistortion diode bias current is inserted into the IC at pins 2 and 15. The gain of each VCA is controlled by the I_{ABC} current (pins 1 and 16), this current being derived from a pair of complementary control voltages. As the gain of the channel increases the other decreases. Some interesting effects can be obtained with this circuit; for example a note can pan from left to right every time it is played.

The VCAs mentioned so far have all been two quadrant multipliers. The operation of a four quadrant multiplier (sometimes called a balanced modulator or ring modulator) is very different (Fig. 12). When two sine waves are multiplied together the result is a signal composed of sum and difference tones. For example, if the two input sine waves have frequencies of 100 Hz and 1 kHz, then the output will be composed of two tones, one at 1100 Hz (sum) and one at 900 Hz (difference). If the same sine wave is applied to both inputs, then the sum tone is twice the original frequency, and the difference tone is a DC voltage. Ring modulators are used to produce discordant sounds and special effects.

Figure 13 is a simple ring modulator circuit. The performance suffers a bit from poor X and Y feedthrough, which can be minimized by adjustment of the two presets. A better modulator is shown in Fig. 14; this circuit employs a balanced modulator chip made by National Semiconductor and others. The feedthrough adjustments are very sensitive and so it is necessary to run the circuit from a stable pair of supply rails. Adjustment of the presets is as follows. Insert a carrier signal (1 kHz at 2 Vpp), look at the output and adjust the carrier fundamental and then the carrier second harmonic presets for minimum feedthrough. Repeat this for the signal path. Feedthrough should be the order of 60 dB down on the maximum output level.

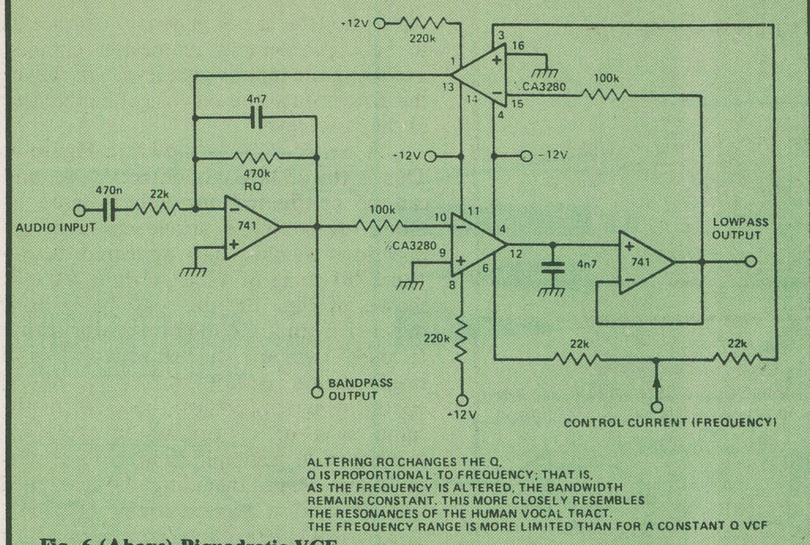


Fig. 6 (Above) Biquadratic VCF.

Fig. 7 Biquadratic lowpass response.

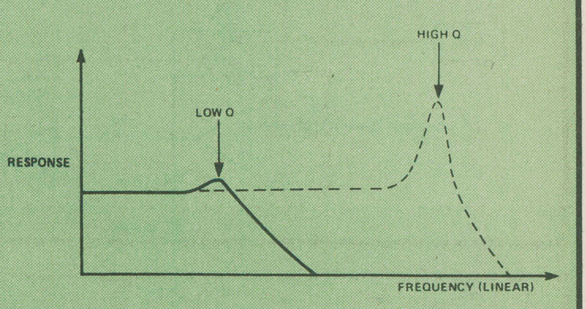
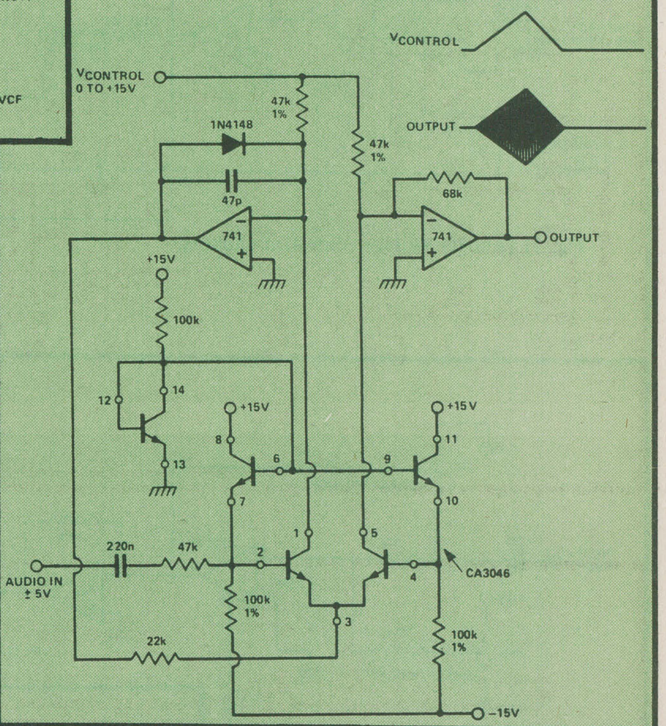


Fig. 10 (Below) Discrete VCA.



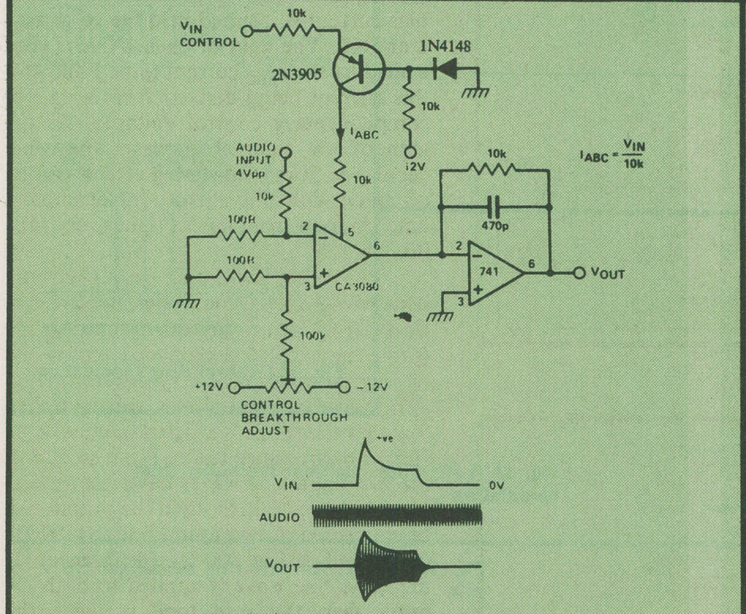
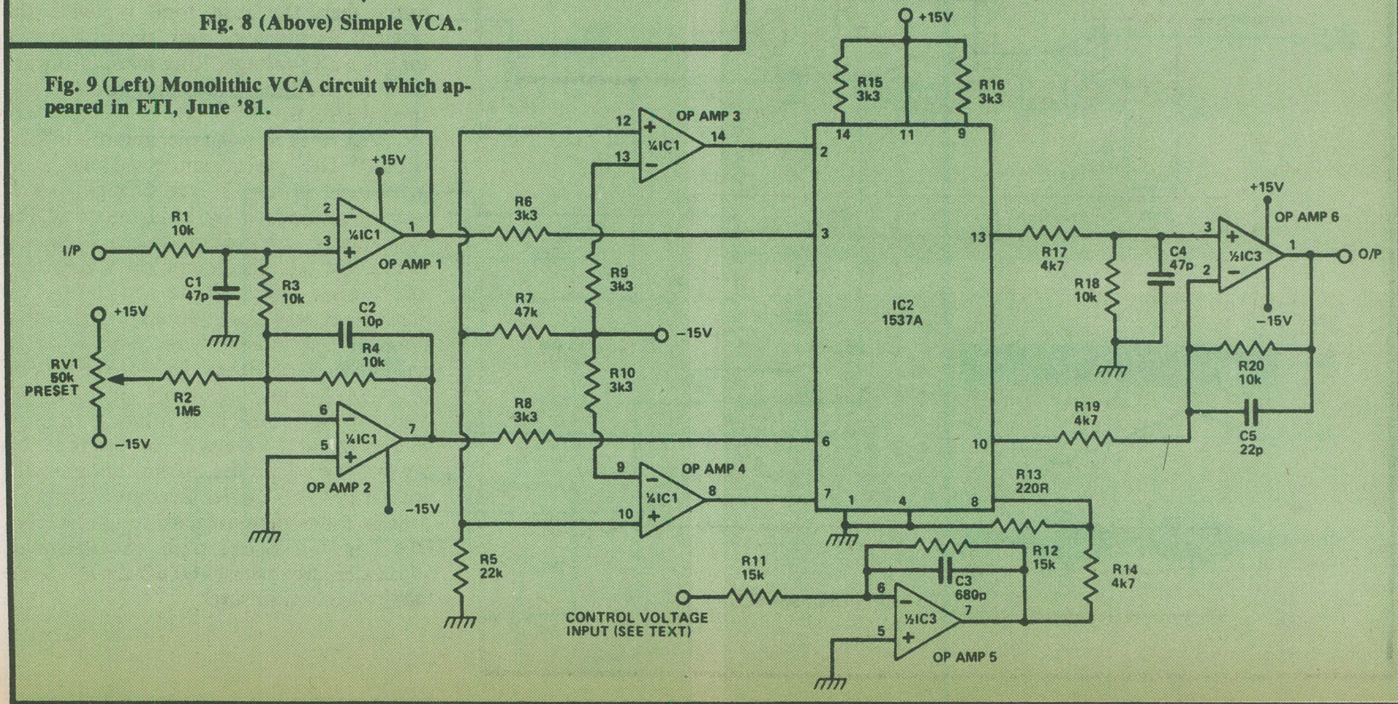


Fig. 8 (Above) Simple VCA.

Fig. 9 (Left) Monolithic VCA circuit which appeared in ETI, June '81.



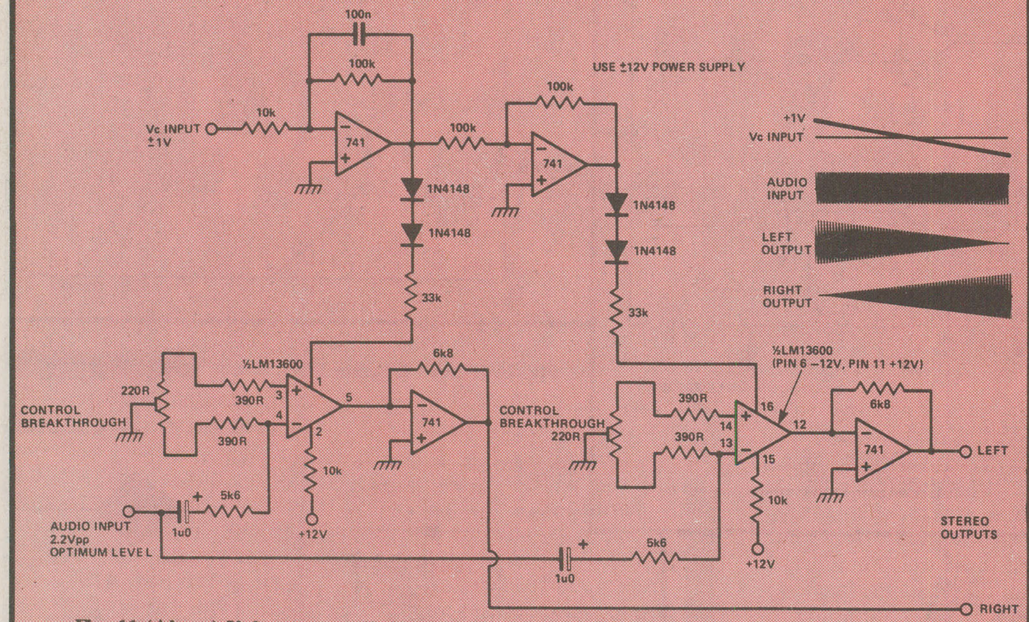


Fig. 11 (Above) Voltage controlled panning.

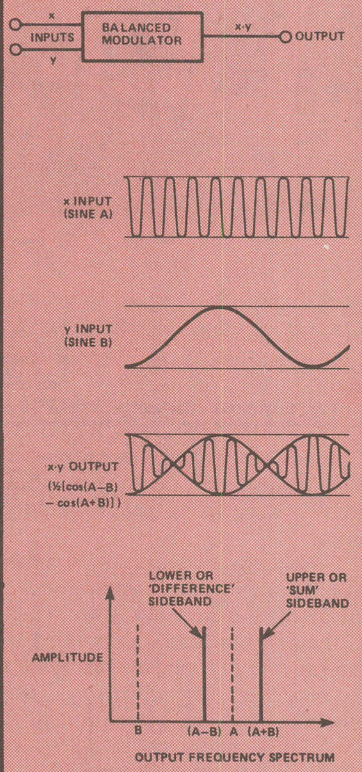
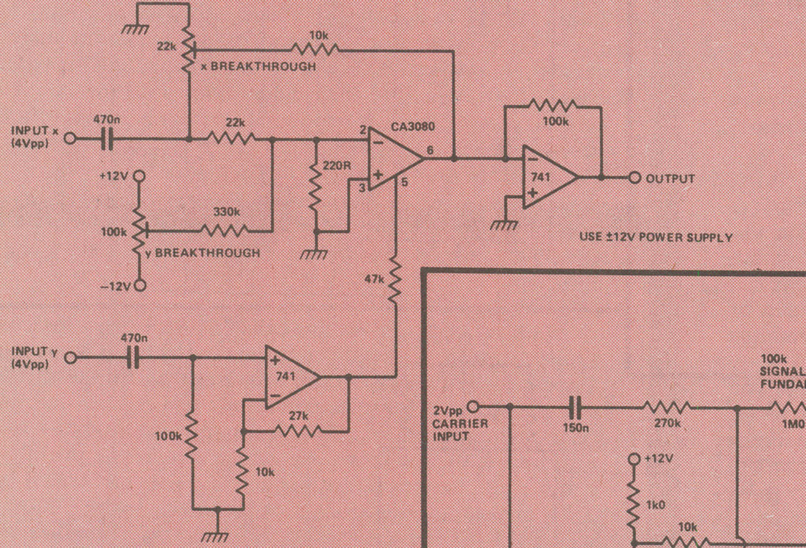


Fig. 12 (Above) Ring modulation.



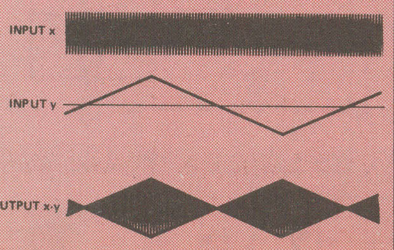
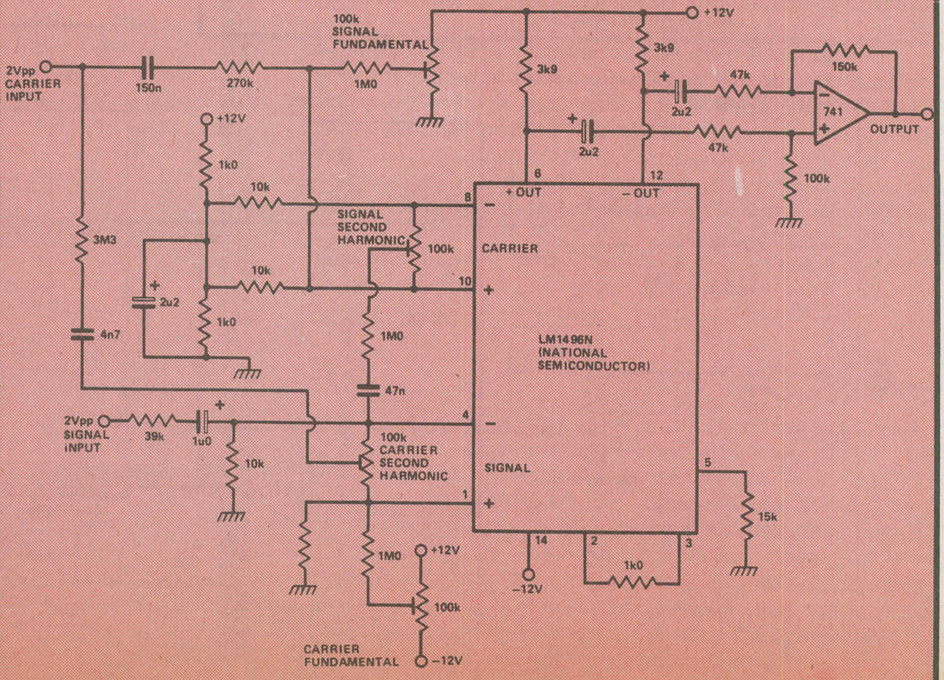


Fig. 13 (Left) Four quadrant multiplier (ring modulator).

Fig. 14 (Below) Another ring modulator circuit.



MOST SMALL computers come with, or can be fitted with, machine language monitors. Some, like the TIM for the PET, are pretty simple and unadorned. They let you look at bytes, change bytes, look at the registers and turn a program loose. If you step up to a slightly more complex system, such as that found on the Apple, you'll find that the monitor offers some tools to help you fool around with all those weird numbers.

At this point, one begins to realize that machine language doesn't have to be totally impossible to work, although it helps.

When you write machine code on paper, you usually do it with the aid of mnemonics, that is, names for the actions that the associated bytes carry out when executed by the processor (if the program doesn't crash before it gets to them). This is a tad easier than trying to read a block of numbers. In fact, there are programs that will take a string of these mnemonics and convert them into bytes for you. You can also go the other way. These things, called assemblers and disassemblers, are a quantum leap in programming.

As it turns out, assemblers are rather more useful than disassemblers because if you get the right type of the former, you don't need the latter.

There are two types of assemblers. The first is the interpretive, or "mini" assembler, as found in the Apple's Integer BASIC monitor and the CP/M "DDT" program. With this program, you type a line of mnemonic text and the program analyses it, and if it's not fraught with syntax trolls, makes it into bytes. However, what you wind up with at the end of writing a program in this way is still a mass of undifferentiated bytes . . . fun if you're looking for a bug.

The second trip is the text assembler. In this case, you create a text file that has your program in mnemonic form, complete with comments and other good bits, and store it on a disk. Then a program is called to read the file and make an object file from it. Some assemblers will immediately churn out a runnable machine code program. Others will produce an intermediate file which must then be linked or loaded to wind up with something useful.

This second sort of assembler is what you've got to get into if you want to do complex code. However, there are a few differences between assembling in this way and just juggling bytes.

New directives

The complicated bits in using an assembler are involved in telling the assembler what exactly you want to do. These are called "directives". Strangely enough, the ways that these things are specified are somewhat universal, even for assemblers designed for totally different processors. For example, the Applesoft Toolkit assembler, still one of the better 6502 packages, and the CP/M 8080 ASM have nearly identical syntax in many of the more global respects.

Here's a quick look at exactly how the funny bits work.

First off, as you have probably figured, if you've checked out the manual for an assembler, the program assembles text files; it doesn't create them. You'll need a text editor or word processor for this. If you think of your text editor's buffer as being a long strip of paper, there are a number of lines in that hard-to-read blue ink that runs vertically, dividing it up into columns which the instructions call fields. We won't, though; fields are big grassy things with old tires in them. Each field is set up to hold a particular part of each line of code written for the assembler to assemble; the program will differentiate between the parts by looking to see what is in each column.

For the purposes of this discussion, let's say that to go from the first to the second column you hit a tab on your keyboard, or control I. Actually, many assemblers are not this specific about where one field ends and the next begins.

The first column is for holding labels. These are references that the assembler can use to branch and jump to, and to call things by. The second column holds the mnemonics for the instructions we want to write. The third column holds the data for the instructions in the second column, and the last column, which extends to the right roughly until forever, is for comments and other stuff the computer doesn't have to know about.

A line of assembler code might read:

```
START   JMP    BEGIN      ;Here's where it gets going
```

This means that a routine called START has a JMP as its first instruction. The stuff after the semi-colon is a comment. Assemblers will always ignore whatever they find to the right of a semi-colon. This is very useful for things other than comments. Suppose you wanted to assemble this program and see what happens if the above line were left out. You could erase it, but you'd have to remember where it goes and type it back in if it turned out to be needed. A better way is to "comment" it out.

```
;START  JMP    BEGIN      ;Here's where it gets going
```

When you want it back, just take out the semi-colon. The first statement in an assembler file is usually an ORG. This tells the assembler where in memory the program will eventually reside when it runs. Most systems have an address where one conventionally begins programs. For example, CP/M programs usually begin at 100H, so the first line is usually:

```
        ORG    0100H      ;Begin here
```

After the ORG, you usually find the equates and variables. Equates are what the assembler calls its constants. For example, suppose one wanted to print a line feed character somewhere in the program. You could print the character AH, but it is often easier to define a variable name with this value.

You'd do this with an EQU.

```
LF        EQU    OAH          ;Line feed
```

If you are going to be getting data from somewhere and you want to store it in RAM, you will have to reserve some space for it. To do this, you would define space, using a DS.

```
BUFFER    DS     40H          ;Input buffer
```

This means to find a place in RAM 40H characters long and store stuff destined for BUFFER there. Later on in the program, putting stuff in BUFFER will just involve loading data into this variable name. For example:

```
GETLINE JSR    GETCHAR      ;Get a character
        CMP    #$0DH        ;Is it a carriage return?
        BEQ    NEXT         ;If so, we're done
        STA    BUFFER,X     ;Load it into the next space in
                            ;BUFFER (Location BUFFER
                            ;+ X)
        INX                 ;Make X point at the next
                            ;space in BUFFER
        JMP    GETLINE      ;Go get another character
NEXT    RET                 ;or whatever
```

There are also two other defines, DB and DW. DB stands for define byte. This means to specify one or more single bytes and put a label to their location so a program can refer to them. DW means define word, or two bytes. This is often used to hold addresses, which are sixteen bits wide in most cases. The CP/M assemblers use DB to hold character strings, among other things.

```
BDOS    EQU    0005H        ;An address to call
        MVI    C,9          ;Tell the system to print
        LXI    D,MESSAGE    ;Point to MESSAGE
        CALL   BDOS         ;BDOS has been defined as an
                            ;EQU
MESSAGE DB     'Electric wombats rule the skies', CR,LF, '$'
;CP/M uses a '$' to mean 'end of message'
```

The lovely bit about using equates and defines in this way is that you can have a huge text file where a reference is used many times. You can put the reference anywhere you like . . . at the top, mayhaps, and by changing it, change all the references in the program on the next compilation.

Most assemblers support something called conditional assembly. This means that you can block off a chunk of code and make its inclusion in your program conditional upon how you define an equate. This may seem like gilding the lily, but it's actually very useful when you start writing programs that can be run on a number of different systems. For example:

```
FALSE   EQU    0            ;You have to do this first
TRUE    EQU    NOT FALSE    ;so assembler will understand
                            ;TRUE and FALSE
;
;This program can be used on the TRS-80 II and the Apple II
;
TRS     EQU    TRUE         ;Set TRUE for TRS-80
APPLE   EQU    FALSE        ;Set TRUE for Apple
;
        IF     TRS          ;If it's a TRS-80
        OUT    MODMPRT      ;Output a byte
        ENDIF
;
        IF     APPLE        ;If it's an Apple
        CALL   MEMMAP       ;Call a routine to
        ENDIF               ;handle Apple's weirdness
```

Of course, we would have to define things like MODMPRT and have a routine called MEMMAP somewhere or the assembler would throw an error. Oh yes, it goes through and checks every reference.

It's interesting to note, though, that most assemblers don't care whether you define a variable or a string prior to the first time it is encountered, just so long as it's defined somewhere in the file.

Finally, there's the END directive. This means just what it looks like . . . it tells the assembler to shut up. You can leave this off in many cases. However, it's handy if you want to temporarily blank off the last part of your file . . . the assembler will ignore anything after the END.

As usual, there's more to it than this. In fact, you will no doubt find specific peculiarities of your assembler. However, given some understanding of the directives used, most of the rest of the programming is done in straight mnemonics . . . if you have been dealing with a mini-assembler up until now, stepping up to one of these things should be fairly easy.

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The writing is nontechnical, allowing almost anyone to understand computerized game playing. The book includes the rules of each game, how each game works, illustrative flowcharts, diagrams, and the output produced by each program. The last chapter contains 26 games for reader solution.

SARGON: A COMPUTER CHESS PROGRAM
SPRACKLEN
HB12 $26.00
"I must rate this chess program an excellent buy for anyone who loves the game." Kilobaud.

Here is the computer chess program that won first place in the first chess tournament at the 1978 West Coast Computer Faire. It is written in Z-80 assembly language, using the TDL macro assembler. It comes complete with block diagram and sample printouts.

A CONSUMER'S GUIDE TO PERSONAL COMPUTING AND MICROCOMPUTERS, SECOND EDITION
FREIBERGER AND CHEW
HB14 $16.45
The first edition was chosen by Library Journal as one of the 100 outstanding sci-tech books of 1978. Now, there's an updated second edition!

Besides offering an introduction to the principles of microcomputers that assumes no previous knowledge on the reader's part, this second edition updates prices, the latest developments in microcomputer technology, and a review of over 100 microcomputer products from over 60 manufacturers.

THE BASIC CONVERSIONS HANDBOOK FOR APPLE, TRS-80, AND PET USERS
BRAIN BANK
HB17 $13.45
Convert a BASIC program for the TRS-80, Apple II, or PET to the form of BASIC used by any other one of those machines. This is a complete guide to converting Apple II and PET-programs to TRS-80, TRS-80 and PET programs to Apple II, TRS-80 and Apple II programs to PET. Equivalent commands are listed for TRS-80 BASIC (Model I, Level II), Applesoft BASIC and PET BASIC, as well as variations for the TRS-80 Model III and Apple Integer BASIC.

SPEAKING PASCAL
BOWEN
HB16 $19.45
An excellent introduction to programming in the Pascal language! Written in clear, concise, non-mathematical language, the text requires no technical background or previous programming experience on the reader's behalf. Top-down structured analysis and key examples illustrate each new idea and the reader is encouraged to construct programs in an organized manner.

BP33: ELECTRONIC CALCULATOR USERS HANDBOOK $4.25
M.H. BABANI, B.Sc.(Eng.)
An invaluable book for all calculator users whatever their age or occupation, or whether they have the simplest or most sophisticated of calculators. Presents formulae, data, methods of calculation, conversion factors, etc., with the calculator user especially in mind, often illustrated with simple examples. Includes the way to calculate using only a simple four function calculator: Trigonometric Functions (Sin, Cos, Tan): Hyperbolic Functions (Sinh, Cosh, Tanh) Logarithms, Square Roots and Powers.

THE MOST POPULAR SUBROUTINES IN BASIC
TAB No.1050 $10.45
An understandable guide to BASIC subroutines which enables the reader to avoid tedium, economise on computer time and makes programs run faster. It is a practical rather than a theoretical manual.

PROJECTS

BP48: ELECTRONIC PROJECTS FOR BEGINNERS $5.90
F.G. RAYER, T.Eng.(CEI), Assoc.IERE
Another book written by the very experienced author — Mr. F.G. Rayer — and in it the newcomer to electronics, will find a wide range of easily made projects. Also, there are a considerable number of actual component and wiring layouts, to aid the beginner.

Furthermore, a number of projects have been arranged so that they can be constructed without any need for soldering and, thus, avoid the need for a soldering iron.

Also, many of the later projects can be built along the lines as those in the 'No Soldering' section so this may considerably increase the scope of projects which the newcomer can build and use.

221: 28 TESTED TRANSISTOR PROJECTS
R.TORRENS $5.50
Mr. Richard Torrens is a well experienced electronics development engineer and has designed, developed, built and tested the many useful and interesting circuits included in this book. The projects themselves can be split down into simpler building blocks, which are shown separated by boxes in the circuits for ease of description, and also to enable any reader who wishes to combine boxes from different projects to realise ideas of his own.

BP49: POPULAR ELECTRONIC PROJECTS $6.25
R.A. PENFOLD
Includes a collection of the most popular types of circuits and projects which, we feel sure, will provide a number of designs to interest most electronics constructors. The projects selected cover a very wide range and are divided into four basic types: Radio Projects, Audio Projects, Household Projects and Test Equipment.

EXPERIMENTER'S GUIDE TO SOLID STATE ELECTRONIC PROJECTS
AB007 $10.45
An ideal sourcebook of Solid State circuits and techniques with many practical circuits. Also included are many useful types of experimenter gear.

BP71: ELECTRONIC HOUSEHOLD PROJECTS $7.70
R. A. PENFOLD
Some of the most useful and popular electronic construction projects are those that can be used in or around the home. The circuits range from such things as '2 Tone Door Buzzer', Intercom, through Smoke or Gas Detectors to Baby and Freezer Alarms.

BP94: ELECTRONIC PROJECTS FOR CARS AND BOATS $8.10
R.A. PENFOLD
Projects, fifteen in all, which use a 12V supply are the basis of this book. Included are projects on Windscreen Wiper Control, Courtesy Light Delay, Battery Monitor, Cassette Power Supply, Lights Timer, Vehicle Immobiliser, Gas and Smoke Alarm, Depth Warning and Shaver Inverter.

BP69: ELECTRONIC GAMES $7.55
R.A. PENFOLD
In this book Mr. R. A. Penfold has designed and developed a number of interesting electronic game projects using modern integrated circuits. The text is divided into two sections, the first dealing with simple games and the latter dealing with more complex circuits.

BP95: MODEL RAILWAY PROJECTS $8.10
Electronic projects for model railways are fairly recent and have made possible an amazing degree of realism. The projects covered include controllers, signals and sound effects: striboard layouts are provided for each project.

BP93: ELECTRONIC TIMER PROJECTS $8.10
F.G. RAYER
Windscreen wiper delay, darkroom timer and metronome projects are included. Some of the more complex circuits are made up from simpler sub-circuits which are dealt with individually.

110 OP-AMP PROJECTS
MARSTON
HB24 $13.45
This handbook outlines the characteristics of the op-amp and present 110 highly useful projects—ranging from simple amplifiers to sophisticated instrumentation circuits.

110 IC TIMER PROJECTS
GILDER
HB25 $11.45
This sourcebook maps out applications for the 555 timer IC. It covers the operation of the IC itself to aid you in learning how to design your own circuits with the IC. There are application chapters for timer-based instruments, automotive applications, alarm and control circuits, and power supply and converter applications.

110 THYRISTOR PROJECTS USING SCRs AND TRIACS
MARSTON
HB22 $13.45
A grab bag of challenging and useful semiconductor projects for the hobbyist, experimenter, and student. The projects range from simple burglar, fire, and water level alarms to sophisticated power control devices for electric tools and trains. Integrated circuits are incorporated wherever their use reduces project costs.

110 CMOS DIGITAL IC PROJECTS
MARSTON
HB23 $11.75
Outlines the operating characteristics of CMOS digital ICs and then presents and discusses 110 CMOS digital IC circuits ranging from inverter gate and logic circuits to electronic alarm circuits. Ideal for amateurs, students and professional engineers.

BP76: POWER SUPPLY PROJECTS $7.30
R.A. PENFOLD
Line power supplies are an essential part of many electronics projects. The purpose of this book is to give a number of power supply designs, including simple unstabilised types, fixed voltage regulated types, and variable voltage stabilised designs, the latter being primarily intended for use as bench supplies for the electronics workshop. The designs provided are all low voltage types for semiconductor circuits.

There are other types of power supply and a number of these are dealt with in the final chapter, including a cassette power supply, Ni-Cad battery charger, voltage step up circuit and a simple inverter.

BP84: DIGITAL IC PROJECTS $8.10
F.G. RAYER, T.Eng.(CEI),Assoc.IERE
This book contains both simple and more advanced projects and it is hoped that these will be found of help to the reader developing a knowledge of the workings of digital circuits. To help the newcomer to the hobby the author has included a number of board layouts and wiring diagrams. Also the more ambitious projects can be built and tested section by section and this should help avoid or correct faults that could otherwise be troublesome. An ideal book for both beginner and more advanced enthusiast alike.

BP67: COUNTER DRIVER AND NUMERAL DISPLAY PROJECTS $7.55
F.G. RAYER, T.Eng.(CEI), Assoc. IERE
Numeral indicating devices have come very much to the forefront in recent years and will, undoubtedly, find increasing applications in all sorts of equipment. With present day integrated circuits, it is easy to count, divide and display numerically the electrical pulses obtained from a great range of driver circuits.

In this book many applications and projects using various types of numeral displays, popular counter and driver IC's etc. are considered.

BP73: REMOTE CONTROL PROJECTS $8.60
OWEN BISHOP
This book is aimed primarily at the electronics enthusiast who wishes to experiment with remote control. Full explanations have been given so that the reader can fully understand how the circuits work and can more easily see how to modify them for other purposes, depending on personal requirements. Not only are radio control systems considered but also infra-red, visible light and ultrasonic systems as are the use of Logic ICs and Pulse position modulation etc.

BP99: MINI—MATRIX BOARD PROJECTS $8.10
R.A. PENFOLD
Twenty useful projects which can all be built on a 24 x 10 hole matrix board with copper strips. Includes Doorbuzzer, Low-voltage Alarm, AM Radio, Signal Generator, Projector Timer, Guitar Headphone Amp, Transistor Checker and more.

BP103: MULTI-CIRCUIT BOARD PROJECTS $8.10
R.A. PENFOLD
This book allows the reader to build 21 fairly simple electronic projects, all of which may be constructed on the same printed circuit board. Wherever possible, the same components have been used in each design so that with a relatively small number of components and hence low cost, it is possible to make any one of the projects or by re-using the components and P.C.B. all of the projects.

BP107: 30 SOLDERLESS BREADBOARD PROJECTS — BOOK 1 $9.35
R.A. PENFOLD
A "Solderless Breadboard" is simply a special board on which electronic circuits can be built and tested. The components used are just plugged in and unplugged as desired. The 30 projects featured in this book have been specially designed to be built on a "Verobloc" breadboard. Wherever possible the components used are common to several projects, hence with only a modest number of reasonably inexpensive components it is possible to build, in turn, every project shown.

BP106: MODERN OP-AMP PROJECTS $8.10
R.A. PENFOLD
Features a wide range of constructional projects which make use of op-amps including low-noise, low distortion, ultra-high input impedance, high slew-rate and high output current types.

BP110: HOW TO GET YOUR ELECTRONIC PROJECTS WORKING $8.10
R.A. PENFOLD
We have all built circuits from magazines and books only to find that they did not work correctly, or at all, when first switched on. The aim of this book is to help the reader overcome just these problems by indicating how and where to start looking for many of the common faults that can occur when building up projects.

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BP110: HOW TO GET YOUR ELECTRONIC PROJECTS WORKING $8.10
R.A. PENFOLD
We have all built circuits from magazines and books only to find that they did not work correctly, or at all, when first switched on. The aim of this book is to help the reader overcome just these problems by indicating how and where to start looking for many of the common faults that can occur when building up projects.

CIRCUITS

BP80: POPULAR ELECTRONIC CIRCUITS — BOOK 1 $8.25
R.A. PENFOLD
Another book by the very popular author, Mr. R.A. Penfold, who has designed and developed a large number of various circuits. These are grouped under the following general headings; Audio Circuits, Radio Circuits, Test Gear Circuits, Music Project Circuits, Household Project Circuits and Miscellaneous Circuits.

BP98: POPULAR ELECTRONIC CIRCUITS, BOOK 2 $9.35
R.A. PENFOLD
70 plus circuits based on modern components aimed at those with some experience.

The GIANT HANDBOOK OF ELECTRONIC CIRCUITS
TAB No.1300 $28.45
About as twice as thick as the Webster's dictionary, and having many more circuit diagrams, this book is ideal for any experimenter who wants to keep amused for several centuries. If there isn't a circuit for it in here, you should have no difficulty convincing yourself you don't really want to build it.

BP39: 50 (FET) FIELD EFFECT TRANSISTOR PROJECTS $5.50
F.G. RAYER, T.Eng.(CEI),Assoc.IERE
Field effect transistors (FETs), find application in a wide variety of circuits. The projects described here include radio frequency amplifiers and converters, test equipment and receiver aids, tuners, receivers, mixers and tone controls, as well as various miscellaneous devices which are useful in the home.
This book contains something of particular interest for every class of enthusiast — short wave listener, radio amateur, experimenter or audio devotee.

BP87: SIMPLE L.E.D. CIRCUITS $5.90
R.N. SOAR
Since it first appeared in 1977, Mr. R.N. Soar's book has proved very popular. The author has developed a further range of circuits and these are included in Book 2. Projects include a Transistor Tester, Various Voltage Regulators, Testers and so on.

BP42: 50 SIMPLE L.E.D. CIRCUITS $3.55
R.N. SOAR
The author of this book, Mr. R.N. Soar, has compiled 50 interesting and useful circuits and applications, covering many different branches of electronics, using one of the most inexpensive and freely available components — the Light Emitting Diode (L.E.D.). A useful book for the library of both beginner and more advanced enthusiast alike.

BP82: ELECTRONIC PROJECTS USING SOLAR CELLS $8.10
OWEN BISHOP
The book contains simple circuits, almost all of which operate at low voltage and low currents, making them suitable for being powered by a small array of silicon cells. The projects cover a wide range from a bicycle speedometer to a novelty 'Duck Shoot'; a number of power supply circuits are included.

BP37: 50 PROJECTS USING RELAYS, SCR's & TRIACS $5.50
F.G.RAYER, T.Eng.(CEI),Assoc.IERE
Relays, silicon controlled rectifiers (SCR's) and bi-directional triodes (TRIACs) have a wide range of applications in electronics today. This book gives tried and practical working circuits which should present the minimum of difficulty for the enthusiast to construct. In most of the circuits there is a wide latitude in component values and types, allowing easy modification of circuits or ready adaptation of them to individual needs.

BP44: IC 555 PROJECTS $7.55
E.A. PARR, B.Sc.,C.Eng., M.I.E.E.
Every so often a device appears that is so useful that one wonders how life went on before without it. The 555 timer is such a device. Included in this book are Basic and General Circuits, Motor Car and Model Railway Circuits, Alarms and Noise Makers as well as a section on the 556, 558 and 559 timers.

BP24: 50 PROJECTS USING IC741 $4.25
RUDI & UWE REDMER
This book, originally published in Germany by TOPP, has achieved phenomenal sales on the Continent and Babani decided, in view of the fact that the integrated circuit used in this book is inexpensive to buy, to make this unique book available to the English speaking reader. Translated from the original German with copious notes, data and circuitry, a "must" for everyone whatever their interest in electronics.

BP83: VMOS PROJECTS $8.20
R.A. PENFOLD
Although modern bipolar power transistors give excellent results in a wide range of applications, they are not without their drawbacks or limitations. This book will primarily be concerned with VMOS power FETs although power MOSFETs will be dealt with in the chapter on audio circuits. A number of varied and interesting projects are covered under the main headings of: Audio Circuits, Sound Generator Circuits, DC Control Circuits and Signal Control Circuits.

BP65: SINGLE IC PROJECTS $6.55
R.A.PENFOLD
There is now a vast range of ICs available to the amateur market, the majority of which are not necessarily designed for use in a single application and can offer unlimited possibilities. All the projects contained in this book are simple to construct and are based on a single IC. A few projects employ one or two transistors in addition to an IC but in most cases the IC is the only active device used.

BP97: IC PROJECTS FOR BEGINNERS $8.10
F.G. RAYER
Covers power supplies, radio, audio, oscillators, timers and switches. Aimed at the less experienced reader, the components used are popular and inexpensive.

BP88: HOW TO USE OP AMPS $9.35
E.A. PARR
A designer's guide covering several op amps, serving as a source book of circuits and a reference book for design calculations. The approach has been made as non-mathematical as possible.

IC ARRAY COOKBOOK
JUNG
HB26 $14.25
A practical handbook aimed at solving electronic circuit application problems by using IC arrays. An IC array, unlike specific-purpose ICs, is made up of uncommitted IC active devices, such as transistors, resistors, etc. This book covers the basic types of such ICs and illustrates with examples how to design with them. Circuit examples are included, as well as general design information useful in applying arrays.

BP50: IC LM3900 PROJECTS $5.90
H.KYBETT,B.Sc., C.Eng.
The purpose of this book is to introduce the LM3900 to the Technician, Experimenter and the Hobbyist. It provides the groundwork for both simple and more advanced uses, and is more than just a collection of simple circuits or projects.
Simple basic working circuits are used to introduce this IC. The LM3900 can do much more than is shown here, this is just an introduction. Imagination is the only limitation with this useful and versatile device. But first the reader must know the basics and that is what this book is all about.

223: 50 PROJECTS USING IC CA3130 $5.50
R.A.PENFOLD
In this book, the author has designed and developed a number of interesting and useful projects which are divided into five general categories: I — Audio Projects II — R.F. Projects III — Test Equipment IV — Household Projects V — Miscellaneous Projects.

224: 50 CMOS IC PROJECTS $4.25
R.A. PENFOLD
CMOS IC's are probably the most versatile range of digital devices for use by the amateur enthusiast. They are suitable for an extraordinary wide range of applications and are also some of the most inexpensive and easily available types of IC.
Mr. R.A. Penfold has designed and developed a number of interesting and useful projects which are divided into four general categories: I — Multivibrators II — Amplifiers and Oscillators III — Trigger Devices IV — Special Devices.

THE ACTIVE FILTER HANDBOOK
TAB No.1133 $14.45
Whatever your field — computing, communications, audio, electronic music or whatever — you will find this book the ideal reference for active filter design.
The book introduces filters and their uses. The basic math is discussed so that the reader can tell where all design equations come from. The book also presents many practical circuits including a graphic equalizer, computer tape interface and more.

DIGITAL ICS — HOW THEY WORK AND HOW TO USE THEM
AB004 $11.45
An excellent primer on the fundamentals of digital electronics. This book discusses the nature of gates and related concepts and also deals with the problems inherent to practical digital circuits.

MASTER HANDBOOK OF 1001 PRACTICAL CIRCUITS
TAB No.800 $20.45
MASTER HANDBOOK OF 1001 MORE PRACTICAL CIRCUITS
TAB No.804 $24.45
Here are transistor and IC circuits for just about any application you might have. An ideal source book for the engineer, technician or hobbyist. Circuits are classified according to function, and all sections appear in alphabetical order.

THE MASTER IC COOKBOOK
TAB No.1199 $18.45
If you've ever tried to find specs for a so called 'standard' chip, then you'll appreciate this book. C.L. Hallmark has compiled specs and pinout for most types of ICs that you'd ever want to use.

ELECTRONIC DESIGN WITH OFF THE SHELF INTEGRATED CIRCUITS
AB016 $13.45
This practical handbook enables you to take advantage of the vast range of applications made possible by integrated circuits. The book tells how, in step by step fashion, to select components and how to combine them into functional electronic systems. If you want to stop being a "cookbook hobbyist", then this is the book for you.

AUDIO

BP90: AUDIO PROJECTS $8.10
F.G. RAYER
Covers in detail the construction of a wide range of audio projects. The text has been divided into preamplifiers and mixers, power amplifiers, tone controls and matching and miscellaneous projects.

205: FIRST BOOK OF HI-FI LOUDSPEAKER ENCLOSURES $3.55
B.B. BABANI
This book gives data for building most types of loudspeaker enclosure. Includes corner reflex, bass reflex, exponential horn, folded horn, tuned port, klipschorn labyrinth, tuned column, loaded port and multi speaker panoramic. Many clear diagrams for every construction showing the dimensions necessary.

BP47: MOBILE DISCOTHEQUE HANDBOOK $5.90
COLIN CARSON
The vast majority of people who start up "Mobile Discos" know very little about their equipment or even what to buy. Many people have wasted a "small fortune" on poor, unnecessary or badly matched apparatus.
The aim of this book is to give you enough information to enable you to have a better understanding of many aspects of "disco" gear.

HOW TO BUILD A SMALL BUDGET RECORDING STUDIO FROM SCRATCH. . .
TAB No.1166 $16.45
The author, F. Alton Everest, has gotten studios together several times, and presents twelve complete, tested designs for a wide variety of applications. If all you own is a mono cassette recorder, you don't need this book. If you don't want your new four track to wind up sounding like one, though, you shouldn't be without it.

BP51: ELECTRONIC MUSIC AND CREATIVE TAPE RECORDING $5.50
M.K. BERRY
Electronic music is the new music of the Twentieth Century. It plays a large part in "pop" and "rock" music and, in fact, there is scarcely a group without some sort of synthesiser or other effects generator.
This book sets out to show how electronic music can be made at home with the simplest and most inexpensive of equipment. It then describes how the sounds are generated and how these may be recorded to build up the final composition.

BP74: ELECTRONIC MUSIC PROJECTS $7.70
R.A. PENFOLD
Although one of the more recent branches of amateur electronics, electronic music has now become extremely popular and there are many projects which fall into this category. The purpose of this book is to provide the constructor with a number of practical circuits for the less complex items of electronic music equipment, including such things as a Fuzz Box, Waa-Waa Pedal, Sustain Unit, Reverberation and Phaser-Units, Tremelo Generator etc.

BP81: ELECTRONIC SYNTHESISER PROJECTS $7.30
M.K. BERRY
One of the most fascinating and rewarding applications of electronics is in electronic music and there is hardly a group today without some sort of synthesiser or effects generator. Although an electronic synthesiser is quite a complex piece of electronic equipment, it can be broken down into much simpler units which may be built individually and these can then be used or assembled together to make a complete instrument.

ELECTRONIC MUSIC SYNTHESIZERS
TAB No.1167 $11.45
If you're fascinated by the potential of electronics in the field of music, then this is the book for you. Included is data on synthesizers in general as well as particular models. There is also a chapter on the various accessories that are available.

TEST EQUIPMENT

BP75: ELECTRONIC TEST EQUIPMENT CONSTRUCTION $7.30
F.G. RAYER, T.Eng. (CEI), Assoc. IERE
This book covers in detail the construction of a wide range of test equipment for both the Electronics Hobbyists and Radio Amateur. Included are projects ranging from an FET Amplified Voltmeter and Resistance Bridge to a Field Strength Indicator and Heterodyne Frequency Meter. Not only can the home constructor enjoy building the equipment but the finished projects can also be usefully utilised in the furtherance of his hobby.

See order form in this issue. All prices include shipping. No

99 TEST EQUIPMENT PROJECTS YOU CAN BUILD
TAB No.805 **$16.45**
An excellent source book for the hobbyist who wants to build up his work bench inexpensively. Projects range from a simple signal tracer to a 50MHz frequency counter. There are circuits to measure just about any electrical quantity: voltage, current, capacitance, impedance and more. The variety is endless and includes just about anything you could wish for!

HOW TO GET THE MOST OUT OF LOW COST TEST EQUIPMENT
AB017 **$10.45**
Whether you want to get your vintage 1960 'TestRite'signal generator working, or you've got something to measure with nothing to measure it with, this is the book for you. The author discusses how to maximize the usefulness of cheap test gear, how to upgrade old equipment, and effective test set ups.

THE POWER SUPPLY HANDBOOK
TAB No.806 **$16.45**
A complete one stop reference for hobbyists and engineers. Contains high and low voltage power supplies of every conceivable type as well mobile and portable units.

BP70: TRANSISTOR RADIO FAULT-FINDING CHART **$2.40**
CHAS. E. MILLER
Across the top of the chart will be found four rectangles containing brief descriptions of various faults; vis: — sound weak but undistorted; set dead; sound low or distorted and background noises. One then selects the most appropriate of these and following the arrows, carries out the suggested checks in sequence until the fault is cleared.

ELECTRONIC TROUBLESHOOTING HANDBOOK
AB019 **$12.45**
This workbench guide can show you how to pinpoint circuit troubles in minutes, how to test anything electronic, and how to get the most out of low cost test equipment. You can use any and all of the time-saving shortcuts to rapidly locate and repair all types of electronic equipment malfunctions.

COMPLETE GUIDE TO READING SCHEMATIC DIAGRAMS
AB018 **$10.45**
A complete guide on how to read and understand schematic diagrams. The book teaches how to recognize basic circuits and identify component functions. Useful for technicians and hobbyists who want to avoid a lot of headscratching.

RADIO AND COMMUNICATIONS

BP79: RADIO CONTROL FOR BEGINNERS **$7.30**
F.G. RAYER, T.Eng.(CEI),Assoc.IERE.
The aim of this book is to act as an introduction to Radio Control for beginners to the hobby. The book will commence by dealing with the conditions that are allowable for such things as frequency and power of transmission. This is followed by a "block" explanation of how control-device and transmitter operate and receiver and actuator(s) produce motion in a model.

Details are then given of actual solid state transmitting equipment which the reader can build. Plain and loaded aerials are then discussed and so is the field-strength meter to help with proper setting up.

The radio receiving equipment is then dealt with which includes a simple receiver and also a crystal controlled superhet. The book ends with the electro-mechanical means of obtaining movement of the controls of the model.

BP96: CB PROJECTS **$8.10**
R.A. PENFOLD
Projects include speech processor, aerial booster, cordless mike, aerial and harmonic filters, field strength meter, power supply, CB receiver and more.

222: SOLID STATE SHORT WAVE RECEIVERS FOR BEGINNERS **$5.20**
R.A. PENFOLD
In this book, R.A. Penfold has designed and developed several modern solid state short wave receiver circuits that will give a fairly high level of performance, despite the fact that they use only relatively few and inexpensive components.

BP91: AN INTRODUCTION TO RADIO DXing **$8.10**
This book is divided into two main sections one to amateur band reception, the other to broadcast bands. Advice is given to suitable equipment and techniques. A number of related constructional projects are described.

BP105: AERIAL PROJECTS **$8.10**
R.A. PENFOLD
The subject of aerials is vast but in this book the author has considered practical designs including active, loop and ferrite aerials, which give good performances and are reasonably simple and inexpensive to build. The complex theory and math of aerial design are avoided.

BP46: RADIO CIRCUITS USING IC's **$5.90**
J.B. DANCE, M.Sc.
This book describes integrated circuits and how they can be employed in receivers for the reception of either amplitude or frequency modulated signals. The chapter on amplitude modulated (a.m.) receivers will be of most interest to those who wish to receive distant stations at only moderate audio quality, while the chapter on frequency modulation (f.m.) receivers will appeal to those who desire high fidelity reception.

BP92: ELECTRONICS SIMPLIFIED—CRYSTAL SET CONSTRUCTION **$7.30**
F.A. WILSON
Aimed at those who want to get into construction without much theoretical study. Homewound coils are used and all projects are very inexpensive to build.

REFERENCE

THE BEGINNER'S HANDBOOK OF ELECTRONICS
AB003 **$11.45**
An excellent textbook for those interested in the fundamentals of Electronics. This book covers all major aspects of power supplies, amplifiers, oscillators, radio, television and more.

ELEMENTS OF ELECTRONICS — AN ON-GOING SERIES
F.A. WILSON, C.G.I.A., C.Eng.,
BP62: BOOK 1. The Simple Electronic Circuit and Components **$8.95**
BP63: BOOK 2. Alternating Current Theory **$8.95**
BP64: BOOK 3. Semiconductor Technology **$8.95**
BP77: BOOK 4. Microprocessing Systems And Circuits **$12.30**
BP89: BOOK 5. Communication **$12.30**
The aim of this series of books can be stated quite simply — it is to provide an inexpensive introduction to modern electronics so that the reader will start on the right road by thoroughly understanding the fundamental principles involved.

Although written especially for readers with no more than ordinary arithmetical skills, the use of mathematics is not avoided, and all the mathematics required is taught as the reader progresses.

Each book is a complete treatise of a particular branch of the subject and, therefore, can be used on its own with one proviso, that the later books do not duplicate material from their predecessors, thus a working knowledge of the subjects covered by the earlier books is assumed.

BOOK 1: This book contains all the fundamental theory necessary to lead to a full understanding of the simple electronic circuit and its main components.

BOOK 2: This book continues with alternating current theory without which there can be no comprehension of speech, music, radio, television or even the electricity utilities.

BOOK 3: Follows on semiconductor technology, leading up to transistors and integrated circuits.

BOOK 4: A complete description of the internal workings of microprocessor.

BOOK 5: A book covering the whole communication scene.

BP85: INTERNATIONAL TRANSISTOR EQUIVALENTS GUIDE **$12.25**
ADRIAN MICHAELS
This book will help the reader to find possible substitutes for a popular user-orientated selection of modern transistors. Also shown are the material type, polarity, manufacturer and use. The Equivalents are sub-divided into European, American and Japanese. The products of over 100 manufacturers are included. An essential addition to the library of all those interested in electronics, be they technicians, designers, engineers or hobbyists. Fantastic value for the amount of information it contains.

BP108: INTERNATIONAL DIODE EQUIVALENTS GUIDE **$8.35**
ADRIAN MICHAELS
This book is designed to help the user in finding possible substitutes for a large user orientated selection of the many different types of semiconductor diodes that are available today. Besides simple rectifier diodes also included are Zener diodes, LEDs, Diacs Triacs, Thyristors, Photo diodes and Display diodes.

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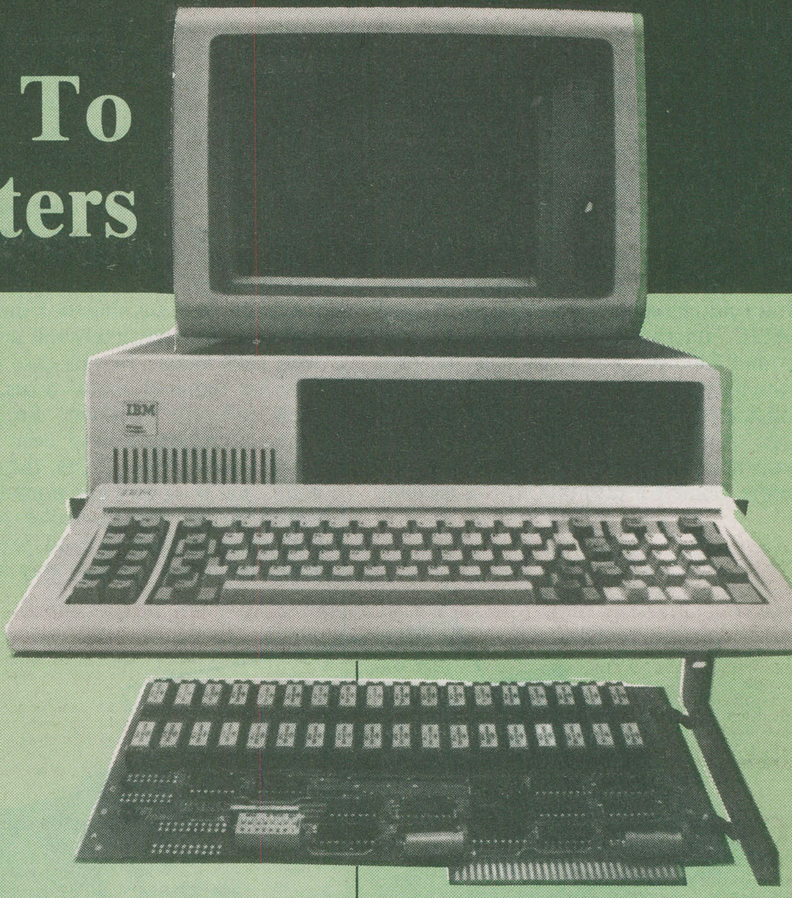
Introduction To Microcomputers



If you feel you're getting left behind in the microcomputer field, Robert Traub gives you a chance to take a look at the subject from the beginning and offers advice on buying a small business system.

THERE HAVE BEEN a great number of microcomputers introduced into the market place over the past few years. Choosing one for personal or business use can be very difficult. This decision can be made easier if a complete understanding of what the system will be required to do is first achieved. Offered here are some points about the microcomputer systems to assist you in understanding some basic requirements for the home or business environment.

The CPU (Central Processing Unit) or MICROPROCESSOR is the heart of the microcomputer system. This is a single LSI (Large Scale Integrated) circuit chip. The rest of the entire microcomputing system is built around this one single unit. There are a number of different types of CPUs from a number of different manufacturers: The CPU in a microcomputer could be an Intel 8080A, Zilog Z80, R.C.A. 1802, Motorola 6502, or 6800, or any of a number of others. All of these microprocessor chips are known as 8-bit types. This designation comes from the fact that the microprocessor's internal registers called the ACCUMULATOR and the INSTRUCTION REGISTER can handle only 8 bits. With this type of microprocessor, 8 bits is referred to as *one byte.* Each type of CPU has its own operating instructions, called the *instruction set.*

Bits and Bytes

The instruction set simply tells the programmer how the 8 different bits are to be set in order to perform different functions. The instruction set would be used by a programmer to develop software; this may be done at the machine level or assembly level. Machine level programming is a type of programming that is done on a bit by bit basis; that is, the programmer must ensure that each bit is set correctly (either a 1 or a 0) and follow each group of 8 bits (one byte) to ensure that the program is correct. With assembly language programming, a program called an *assembler* allows the use of symbols called *op-codes* and *operands.* The assembler will convert these symbols to the appropriate binary bits and bytes and store them in the correct place in the microcomputer's memory or *RAM* (Random Access Memory). Programming that is done in machine language or assembly language is restricted to the particular microprocessor chip. That is, a program written in machine or assembly language for the 1802 will not operate with any of the other types of CPUs. However, there are a group of programming languages that are generally universal and can be used with any microcomputer regardless of the CPU type. These are called *High Level Languages.* One such language is called BASIC (Beginners All-Purpose Symbolic Instruction Code). Whereas programs written in BASIC and other high level languages can be used with any type of CPU, each manufacturer may have a slightly different version of the high level language. But, all in all, programs written in these languages can be made to operate universally. Other high level languages include PASCAL, FORTRAN (FORmula TRANslator), and COBOL (COmmon Business Oriented Language) to name a few. All of these programs will require memory in which to operate.

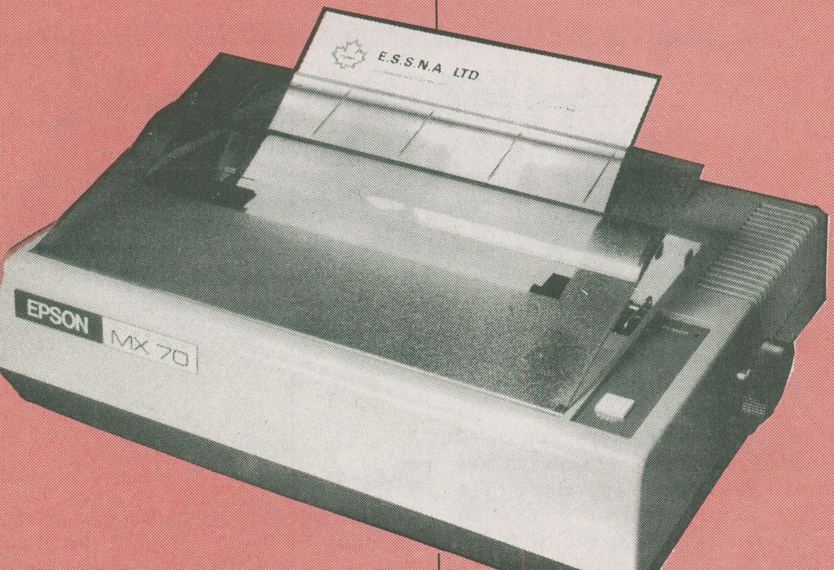
Memory

This brings up the question of how much memory or RAM is needed. As a rule, 64K of RAM will be required by almost all applications. If the computer is going to be used with high level languages, 64k is a must as some BASIC programs, for instance, take up at least 32-40k. A few microcomputers may seem to be very well priced, but this price may include only 16K of RAM. In most applications 16K of RAM is not sufficient, and the cost of another 16K of RAM may be higher later or the RAM may be unavailable. Even with the next 16K of RAM that is only 32K. This amount still does not meet the minimum required for high level languages. Assembly language programs do not require as much RAM, however the programs that you develop on the system may get rather large with source code and require the extra space. The best bet is to consider the original purchase with the maximum amount of RAM. This will give a true cost picture of the basic microcomputer and save up setting things right later on. Adding memory may require software and/or hardware changes to the system in order for the microprocessor to know that more RAM has been installed.

Software

After the microcomputer with RAM has been purchased, the next thing required is software. If programming is what one wants to do, then the purchase of either an assembler or high level language will be necessary. These programs are expensive and the cost can very quickly exceed the thousand dollar range. The amount will depend on the type and number of programs purchased. As an example, a good BASIC interpreter program can cost around $400.00 U.S. Even then the program may not do exactly as the purchaser anticipated. There are many different versions of BASIC available, some have many added features while others are very simple. Some features that will be needed, if the use includes financial work, are Double Precision Math, Print Using, and of course disk access. Some makes of microcomputers have a small BASIC program included in a ROM (Read Only Memory), and this may restrict any choice.

Programs written for business applications can run from a few dollars to over a thousand dollars each. If a computer system with software is being purchased there is a very good chance that some excellent assembler language programming has been done for the system. These programs might include a word processor, general ledger with A/R and A/P packages, a billing package, some type of communications package for modem and telephone interfacing. There may also be a data base program and facilities for all of these program to interface with each other, to form a complete business system. These type of programs have the ability to protect the end user from all the hard work and file maintenance required by the system. The cost may appear to be excessive for these programs, but they will do the job. With these type of programs the end user may not be able to get the programming code (source code). He must, therefore rely on the dealer for any improvements or modifications that he may feel are needed. Other types of general business program written in BASIC or some other high level language and purchased from different software vendors, likely will not interface with each other. In this case data entry may be required many times, once for each software program. Because these types of programs have been written to cover a wide range of uses, they may need additional programming done in order to trim them to the particular application and improve their overall performance. Here again the vendor may offer programming to customize the package. If not, an outside programmer will have to be found or programming will have to be done yourself. Buying the microcomputer hardware is only one half of the system, and as much or more money should be invested in software. A lot of users dispute the cost of software and programming; however, the hardware can not do one thing without the software, and it is the software that will make everything possible. It would not make much sense to have a large financial investment in hardware (computer equipment) only to have the system perform poorly due to cheap, crude software.



The software requirement is going to be the hardest area in which to achieve satisfaction. There are a number of programs on the market that are well written, but also, there are many that will fall short when used in a business environment. There are not many people in the microcomputing field who are fully qualified in a profession such as accounting, who are also full time programmers and proficient in both subjects. If the programmer fails to understand fully the workings of accounting, then his general ledger program is likely to have more than a few short comings. This of course is true of the accounts payable and accounts receivable programs that may be included with the package. Also if the programmer is not totally familiar with data management, then any data base that is produced will likely fall short in one area or the other. The same thing is true for word processing packages, and these type of programs offer special problems all by themselves. First, if the purchaser buys a very good word processing package, he will soon find that he requires a very sophisticated type of printer.

Printers

Such printers can run in the order of a few thousand dollars. Printers vary greatly in type and print quality, and a dot matrix type of printer with a head matrix of 5 by 7, for instance, is not suited for word processing. Conversely if a sophisticated printer has been purchased it cannot be expected to perform well with poor software. Buying a microcomputer requires a total understanding of the job it will be expected to perform. It should be noted that this is the responsibility of the purchaser and not of the dealer.

Data Storage

The programs that have been purchased will have to be stored on some type of medium. In the beginning, the programs were stored on paper tape. Later, the magnetic tape recorder became popular and there were two types available. One, the digital recorder, can search for data, rewind automatically and is relatively fast. The other type is the standard home cassette audio recorder. This type has to be manually rewound, and the search for data can take a long time. Then came the 8 inch floppy disk drive avd a bit later the smaller 5.25 inch mini floppy disk drives. The disk system allows much faster loading and saving of programs and data. As time went on, these drives improved and the amount of storage area for programs greatly increased as they went from a single sided, single density type of format to the now common double sided, double density format (some even offer QUAD density). The 8 inch drives and their associated diskettes can hold a much larger amount of data than the comparable 5.25 inch drive and diskette. The type and size of drive that is available for the particular microcomputer will more or less determine the amount of storage area for that system. When storage is con-

Continued on page 71

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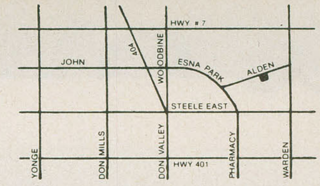

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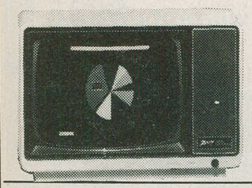

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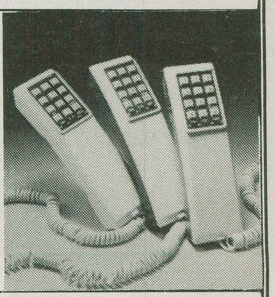

6502 48K board a/t	$409
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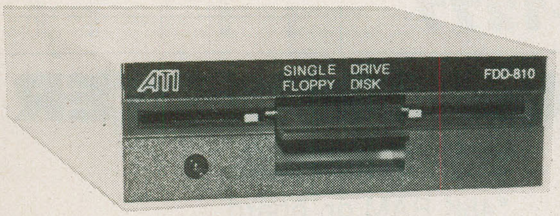

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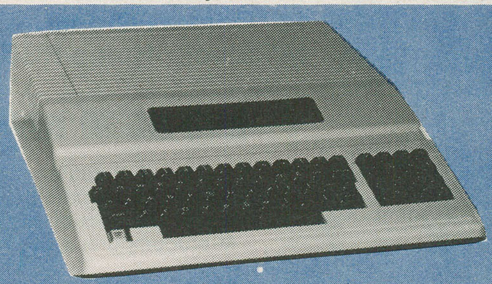

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Continued from page 68

sidered for business, it would begprudent to consider nothing less than an 8 inch drive. Business programs and data can quickly grow, and the need for a lot of storage area will fast become apparent.

With increased demand for storage area, the latest introduction into the microcomputing field is the "hard disk pack". These units can store several millions of bytes of data and are available in either 5.25 inch (5 megabytes) or 8 inch (40 megabytes). Not all of the microcomputer systems currently offer the hard disk packs, but they are coming in the near future. It will not be long before both the cost and the availability of these units improves dramatically. Of all the different storage devices currently available, each will have to be evaluated in order to determine which is right for that application. At this point it is important to note that most programs are distributed on diskette. This is so because most programs require some type of data access, and cassette is simply too slow and awkward to handle the job. Diskettes on the other hand are fast, efficient and reliable. On systems with hard disk packs, the programs are supplied on diskette and transferred onto the hard disk by the user.

I/O

Another item that will be required with the purchase of a microcomputer is a board called an I/O board. I/O means input/output and this is the board that will allow you to interface with the various pieces of external equipment that you may have. These may include video display, printers, plotters, control system etc. The I/O may be one of a few types, it may be a serial I/O which can offer 20 mil loop or RS232C voltage levels. Another type is the parallel I/O port. This type offers interface lines needed by sophisticated printers, digital to analogue boards and some control devices. It will take a bit of investigation, but it should be determined at an early stage, if possible, what type of equipment will be used with the system, and ensure that the correct type of I/O is available. Having a serial RS232C output or parallel output port is only one half of the requirement, each different device will still require software in order to operate correctly with the system.

Maintenance

Maintenance is another consideration. The first microcomputers were used by the electronic hobbyist and amateur programmer. These people had to build, maintain, program, and generally do everything that needed to be done. The various dealers provided technical, service, and programming manuals. The home computerist and business man are in a different situation today, the maintenance manuals and electronic expertise are not always available, nor is the time. It is important that the service arrangement be agreed upon when buying the unit, and that a check is made with other customers to assure that the service is at a standard that you can live with. If the unit is used in business, then reliable, fast service is a must. If a printer is purchased, then the service arrangements for it must also be secured. Generally, each piece of equipment will require some types service agreement; preferably arranged prior to purchase.

Other Points

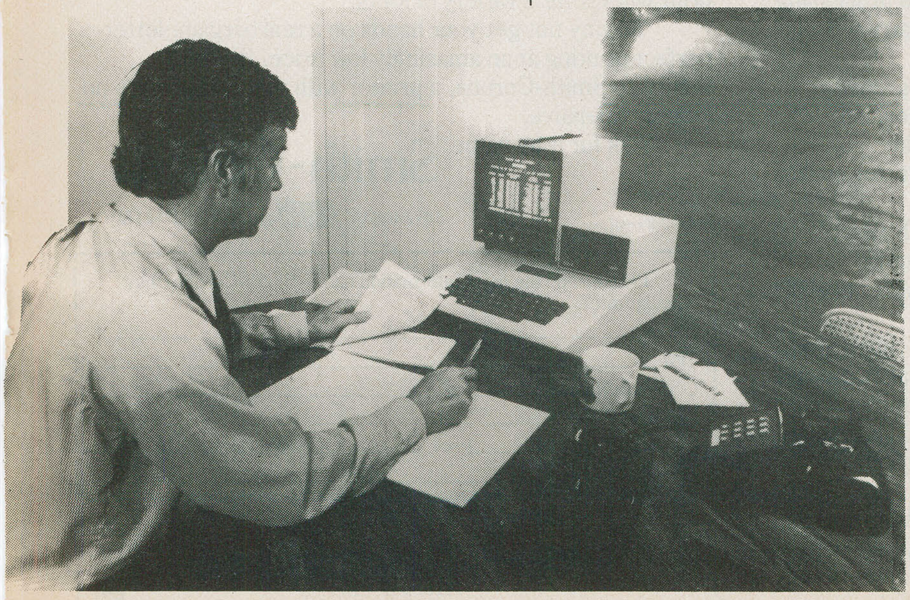
Other points needing consideration are such things as audit trails, security, data access, and other business considerations. If the microcomputer is used in business, it is essential these factors be considered. It will be up to each installation to determine just how data entry security is to be maintained and how access to business information from the system is to be controlled. Along with these considerations the microcomputer also requires a relatively clean environment and must not be in or near excessive temperatures. The care of diskettes is also important, and the wise user will make a second copy of each diskette (back-up copy) and store it in a cool dark place. Diskettes should never be left sitting where the sun can shine on them and heat them up, nor must they be set near the telephone, TV, or any other equipment that can generate an electromagnetic field that may erase the data stored on the diskettes. The reliability of the entire system will depend on how well these factors are considered. Good care, and good security will almost always ensure accurate, reliable data with a minimum of down time.

Current Trends

This is not the end of things but rather just the start. The new breed of microcomputers entering the market in the near future (some are out now) will be of the 16 bit bariety. This size of microcomputer rivals the minicomputer in stature, but has brought the cost down to the level where the small business man can afford to invest in a system. Again, with this system things are developing fast and the technology is keeping on top of all aspects of microcomputing. With the newer 16 bit microcomputers available, we can look for faster, better software from many additional sources. This will allow the user to select from dealers, the complete "system" software and for the user to know exactly what it can do for him before he has to spend his money.

The microcomputer system that is required for a certain application is most likely already available, but it will take some looking and a great deal of asking in order to determine exactly which system to purchase. There are a number of quality systems and business programs as well as general entertainment type programs currently offered. The microcomputers have become very reliable over the past 4 years, and the correct system is definitely worth the investment of time and money.

ETI



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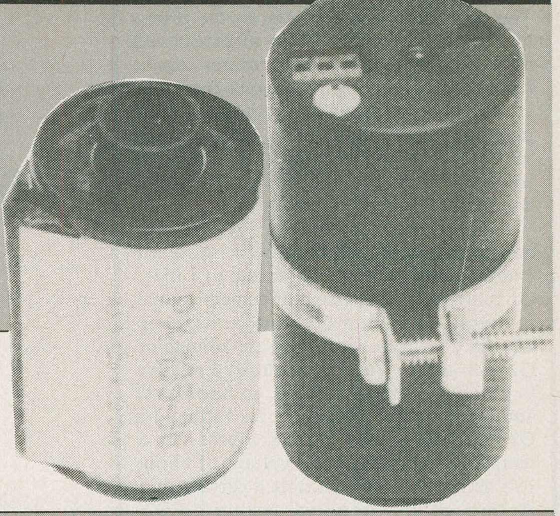


This project will endow a robot with infra-red vision, and it's not much bigger than a human eye-ball. Alternatively you use it in applications such as batch counting. Design and development by Rory Homes.

THIS PROJECT provides a very useful means of detecting the presence of anything by the reflection of infra-red light, and provides a direct digital output of object detection.

The transmitter and receiver of the infra-red beam are both mounted on the same miniaturised PCB, which is housed in a short length of aluminum tube for shielding and protection. By the use of modulation and high power bursts of infra-red at a very low duty cycle, a detection range of over 30 cm is achieved. The receiving photo-amplifier is tuned to the same modulating frequency of 1 kHz, and thus provides good rejection of stray infra-red interference. Bright lights will not affect the operation of the module.

The module features a wide supply voltage range with a LED to indicate correct operation. A preset adjustment pot at the rear of the sensor allows the detection range to be preset at any distance between 1 and 35 cm.

Construction

Although the PCB layout (Fig. 2) is quite dense, with several vertical mounting resistors, the assembly should be straightforward. The only component of note is PR1, a ¾'' 20 turn rectangular cermet preset. These are readily available, though, and should fit the board exactly. The power transistor Q3 is mounted flat, with the metal side face down; likewise, observe the orientation of the other transistors. Photodiode D1 has a chamfered edge on one side; this is mounted to face the infra-red emitter LED2, so allowing the sensitive surface to face outwards. The infra-red LED should be mounted with the flat side facing away from the photodiode (the flat identifies the cathode). After assembly of the board it is important to mount a small guard between the infra-red emitter and detector, to prevent infra-red light passing directly to the detector before it has been reflected. The guard should be a 7 mm square, cut from un-etched PCB or a piece of aluminum. It can be stuck between the two diodes and directly in front of C4 with a blob of epoxy.

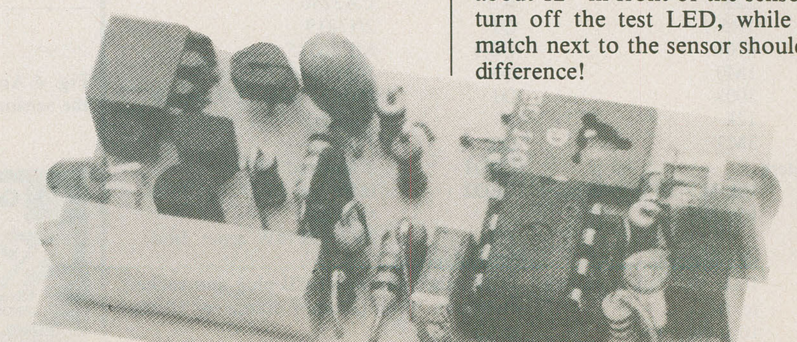
The board is mounted in a 55 mm length of aluminum tube, of internal diameter 27 mm or greater.

The diagram of Fig. 3 illustrates how a nut is soldered sideways onto the PCB track directly beneath the 3-way connecter socket. Holes are drilled in one end of the tube to mate up with the indicator and preset adjustment screw. A rectangular hole also needs to be cut, allowing access to the connector socket. A bolt can now be used to tighten the board against the tube end. The sensing end of the tube may be covered with anything that is transparent to infra-red (red filter plastic polarising sheet, or just clear plastic). If openings are cut for the emitter and detector then an aluminum disc could also be used. The disc should be cut to fit the tube and mounted flush against the small guard plate with epoxy. The sensor tube may be mounted with a circular clamp that tightens round the tube; this can be seen on the photographs of our prototype.

C2, the smoothing capacitor, is shown on the circuit diagram as a 100uF 10V tantalum electrolytic. This value was chosen to fit on the PCB and consequently limits the supply to 9 V maximum, although the circuitry is capable of operating up to 35V. To allow higher supply voltages, change C2 to 22uF 35 V tantalum. An additional electrolytic of 100uF 40 V should be mounted underneath the board and soldered to the same pads as C2.

The sensor is now ready for testing, and the three way connector plug should be wired to a suitable power source capable of providing 100 mA (this is for the benefit of the bulb, if used; the circuit itself only takes 20 mA). A 9 V battery is adequate. One of the test circuits illustrated in Fig. 4 should be adopted; if the LED arrangement is used, for example, the LED will be on when the sensor points into free space. Start with the preset fully anticlockwise; this gives minimum sensitivity and the sensors should not trigger at all.

Keeping the sensor pointed at free-space, the preset should be turned clockwise to increase the sensitivity until the LED just goes out. The preset should now be backed off until the LED just goes out. The preset should now be backed off until the LED just comes on again, thus setting the maximum range. Placing a hand about 12'' in front of the sensor will now turn off the test LED, while striking a match next to the sensor should make no difference!



HOW IT WORKS

The proximity sensor works on the principle of transmitting a beam of modulated infra-red light from the emitter diode LED2, and receiving reflections from objects passing in front of the beam with a photodiode detector D1. The circuit can be split into three distinct stages; the infra-red transmitter, the photodiode amplifier, and a variable threshold comparator.

The transmitter provides 1 A peak current pulses for 10 uS through the infra-red emitter diode, at a repetition rate of 1 kHz. Q1 is arranged as a constant current source to supply the base of Q2, and to charge up C1. As C1 charges up, the base voltage of Q2 rises until it reaches about 0V6 relative to ground. Q2 then turns on, so turning on another constant current source formed by Q3 and LED1. This current source sets a temperature compensated voltage of about 1V5 across R3, thus defining a current of 1 A through the infra-red emitter LED2. After Q3 turns on, a negative pulse through C1 and R2 is set at 10 uS. A 10 uS pulse every 1 mS is equivalent to a duty factor of 1:100, so that although 1 A peak pulses are generated, the average current required is only 10 mA. Capacitors C3 and C2 are there to provide power supply smoothing to decouple the fast current pulses.

The detector is built around IC1, a CA3240 dual op-amp. IC1a is configured as an inverting amplifier with a gain of — 2. It amplifies the infra-red signal picked up by photo-diode D1. C4, which couples the diode signal to IC1a, acts as a high-pass filter in combination with the input impedance of the amplifier. Positive-going pulses of 10 uS duration are fed from the output, via rectifier D2, to a smoothing filter C5 and R9. This provides the signal voltage reference for the inverting input of comparator IC1b. A 2V7 reference, formed by R8 and ZD1, provides the biasing voltage for the photodiode through R7. It also provides the reference voltage for the non-inverting comparator input, set by potential divider PR1.R10 creates positive feedback round the comparator, to improve the switching, and introduce a small amount of hysteresis. Thus, if a reflected light signal received due to the presence of an object rises above the threshold set by PR1, the comparator output will go into negative saturation. The comparator output is used to turn Q4 on or off, thus providing an open collector output for digital interfacing to logic circuits.

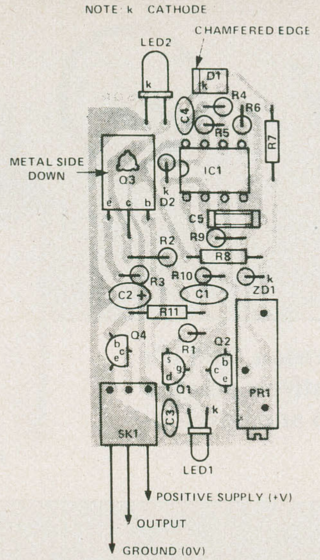


Fig. 1 Component overlay for the optical sensor. The photos overleaf show how small the unit is.

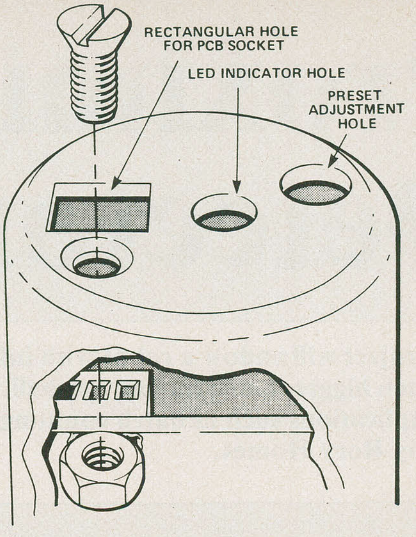


Fig. 3 This is how we mounted the PCB in the aluminum tube. The nut is soldered to the ground track under SK1.

NOTE:
IC1 IS CA3240
Q1 IS 2N3819
Q2,4 ARE MPS6515
Q3 IS BD140 OR TIP30C
D1 IS PHOTODIODE
D2 IS 1N4148
ZD1 IS 2V7 400mW ZENER
LED1 IS 3mm RED LED
LED2 IS INFRA-RED LED

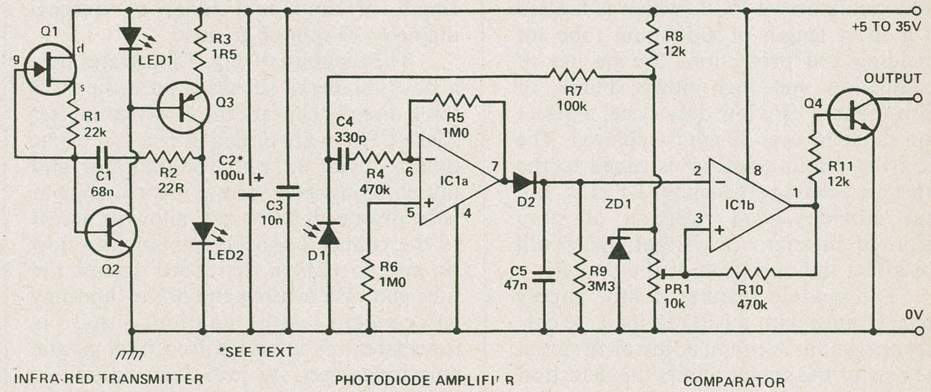


Fig. 2 Circuit diagram for the sensor.

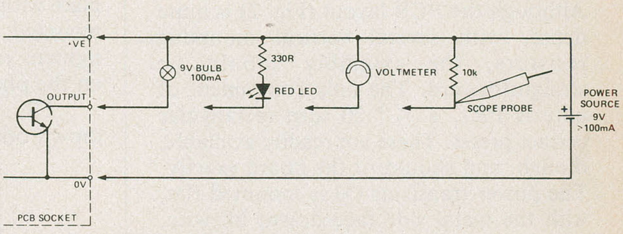
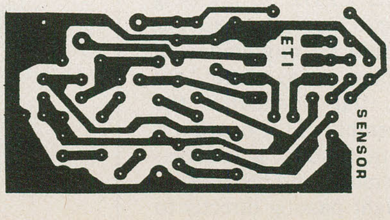


Fig. 4 Any of these test circuits may be used to check out the sensor.



PARTS LIST

Resistors (all ¼W,5%)		C5	47n polycarbonate
R1	22k	**Semiconductors**	
R2	22R	IC1	CA3240
R3	1R5	Q1	2N3819
R4,10	470k	Q2,4	MPS6515
R5,6	1M0	Q3	BD140 or TIP30C
R7	100k	D1	Photo-diode (TIL100 or similar)
R8,11	12k		
R9	3M3	D2	1N4148
Potentiometers		LED1	3 mm red LED
PR1	10k ¾" 20 turn cermet trimmer	LED2	infra-red LED (TIL38 or similar)
Capacitors		ZD1	2V7 400 mW zener diode
C1	68n ceramic	**Miscellaneous**	
C2	100u 10V tantalum (see text)	PCB; any three-way PCB plug and socket; aluminum tube (27 mm diameter, 55 mm long).	
C3	10 n ceramic		
C4	330p ceramic		

Circle No. 21 on Reader Service Card.

EQUAL-TEMPERED SCALE: Some Notes

The musical scale now in common use isn't arbitrarily constructed, but is based on the characteristics of an acoustical note. Bill Markwick looks at its derivation.

IN THIS ISSUE you'll find a list of the frequencies to which the Polyphonic organ should be tuned. These are frequencies of the notes of the equal-tempered scale, also known as the scale of equal temperament; this is the international standard for musical instruments. Primitive man started it all off by being charmed with the various sounds he could get by thumping on a hollow log or his friend's head; present technology has it to the point where you have to listen to canned music when you're put on hold. In between, many centuries of fiddling occurred before arriving at the standard we use today. It's a marvel of mathematical simplicity, and a miracle of compromise when you see how it solves the problems arising from trying to get flexibility out of musical acoustics. Here's a very much condensed explanation in question-and-answer form:

Does a musical scale have to be any specific form?

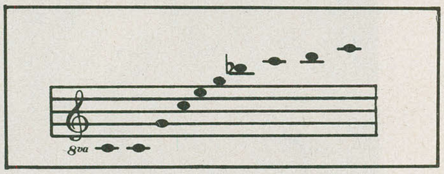
Not really; various cultures have used musical scales that were arbitrary - the pitch of the notes may have been based on drilling random holes in a bamboo flute, or something similar. However, the human brain happens to be able to detect the octave very readily; that's a doubling or halving of pitch. Next in ease of detection comes the fifth, a pitch increase of 50%. The octave and fifth turn up in all folk musics; we're on our way to a formal musical scale.

Is there a difference between pitch and frequency?

Frequency is the repetition rate of a note in cycles per second, or Hertz. Pitch is our subjective perception of frequency; more of this later when we come to the piano keyboard.

So how did the scale happen at all?

It's all based on the fact that a vibrating string or pipe doesn't produce a pure tone; that is, the note produced will be composed of the fundamental, which determines the pitch, and the various harmonics, which determine the colour or timbre of the sound. In the example of a string, for instance, the fundamental vibration first divides in two - this produces the first harmonic, the octave. Then it divides up into a ratio of three to two, and gives us the fifth. As the vibration continues dividing up in simple integer ratios, the notes of a musical scale will be generated. Here's the harmonic series based on a string vibrating at the pitch C.



That's all there is to it?

We've just begun. The fundamental and its harmonics have given us a series of pitches known as the natural scale, so-called because it occurs in any naturally vibrating string or pipe. This natural scale is quite useable; in fact, it was used for centuries. The problem arises with the peculiar spacing between the notes. This spacing results from the fact that the string or pipe divides up its fundamental in simple ratios. Here are a few of those ratios for the key of C:

C		D		E		F
	$\frac{9}{8}$		$\frac{10}{9}$		$\frac{16}{15}$	
264		297		330		352

The ratios between notes and note frequencies for the natural scale based on A = 440 Hz.

Why should this cause problems?

It doesn't really, as long as you stay in the key of C. The fun begins if we try to play in another key. You'll notice that there are three types of tones: the major, the minor and the semitone. For example, C to D is a major tone, D to E is a minor and E to F is a semitone. These three tones, by the way, are peculiar to the natural scale; you won't find them in our equal-tempered scale, but I've shown them anyway as part of the explanation.

Imagine that you're playing away on your natural-scale perforated gourd, and your friend arrives with his natural-scale nose flute which is pitched in the key of D. Your D to E is fixed as a minor tone (10/9). His D to E, however, is fixed as a major tone (9/8) because his D to E is the second note of his scale, i.e. "do" to "re".

It's going to sound terrible when you play together.

If the scale is determined by fixed simple ratios, then each key must have its own set of frequencies!

Exactly. A note, say C, would be different pitches depending on what key you were in.

There's obviously a solution here.

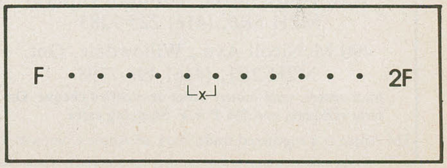
Some centuries before Bach wrote his musical treatise, The Well-Tempered Clavier, someone hit on the idea of dispensing with the three types of tones and constructing the scale out of one building block: the semitone. A whole tone, for instance C to D, would now be made up of two semitones.

And?

It worked like a charm.

How was this arrived at?

Start with any pitch, F, and its octave, 2F. Now divide the interval between them into 12 equal parts, i.e. the percentage change in frequency from any note to its neighbour is always the same throughout the octave. The percentage change from C to C#, for instance, is the same as the change from F to F#, and so on.



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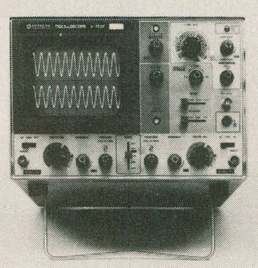

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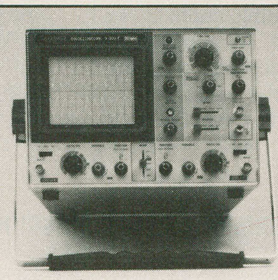
$820



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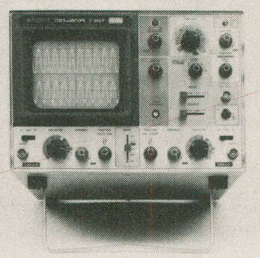
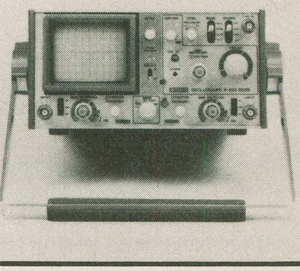


V-302F — 30 MHz
$1,024



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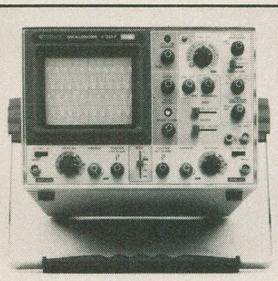

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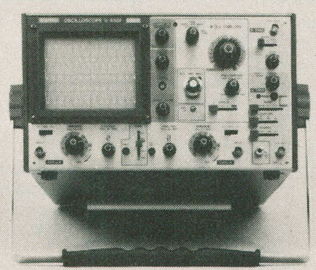

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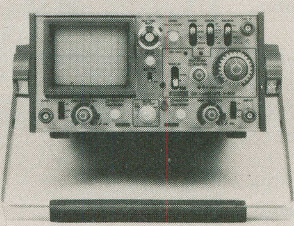

V-509 — 50 MHz
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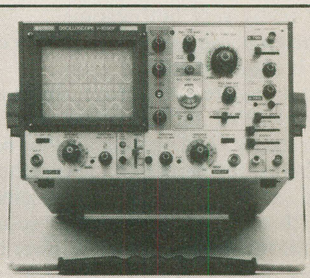

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Equal Tempered Scale

Finding this percentage change is straightforward:

Call the change in pitch X. Now the increase from F to its neighbour will be FX; another semitone up is FXX or FX^2, and so on.

$$\text{Therefore, } FX^{12} = 2F$$
$$X^{12} = 2$$
$$X = \sqrt[12]{2}$$

A poke at the calculator shows X to be 1.059463, or about 5.9%. This is the origin of the mysterious twelfth-root-of-two.

And this works with no problems?

Not entirely. There's something of a clash between the equal-tempered notes you play and the harmonics arising from those notes. For instance, if you play a C note, its harmonic G is based on the natural scale, and grates up against the equal-tempered G note on your fingerboard or keyboard. A beat note will result, but it isn't really very bothersome.

I tuned a piano using a frequency counter, and it sounded sour.

Here's where we leave hard-and-fast physics rules and enter the grey area of subjectivity. The problem is that our pitch vs. frequency perception gets rather out of hand at the frequency extremes: the twelfth root of two no longer sounds like a semitone in the upper and lower octaves. Piano tuners compensate for this by "stretching" the pitch of these errant notes.

What is this Comma of Pythagoras business?

Mr. Pythagoras noted that you could generate all the notes of the scale by jumping ahead in fifths (see the Polyphonic Keyboard project). However, when you get around the circle of fifths to your octave note, the note you're come up with will be slightly sharp from an exact octave. This difference is known as the comma of Pythagoras, for some odd reason. The explanation is simple: we're trying to multiply 1.5 times itself some number of times that will give a multiple of two, and it can't be done; the octave note is unobtainable with a natural-scale fifth. The cure is to use the equal-tempered fifth, which is about 1.49.

Great stuff! I'm dying to research this further.

I'll bet you are. One of the best books ever written on the subject is **Music, Physics and Engineering,** by Harry F. Olson, Dover Books, 1967. It's a bible of musical acoustics. Another good one is **The Oxford Companion to Music,** by Percy A. Scholes, Oxford University Press, 1970.

ETI

Outdoor PA

Continued from page 26

levels, but this is expensive. The higher the speakers can be mounted the further apart they may be spaced. As a rule of thumb, each 5m of height allows a speaker spacing of 50 m.

Wiring

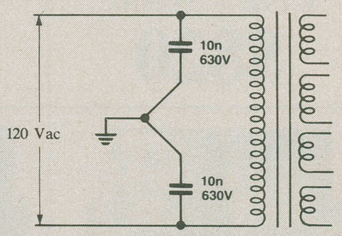
I have found that lighting cable is well suited for wiring 100 V loudspeaker systems. Although somewhat overrated for audio power levels, the cable is durable and cheap, and is easy to strip. Many connections are made with the strip-twist-tape technique atop ladders, and a light fiddly cable is a hassle to use. It is convenient to have fixed lengths of precut cable to avoid constantly breaking and rejoining a single cable.

I have mounted pairs of horn speakers on wooden battens with spring connectors mounted on them. Holes in the battens allow the speakers to be tied to various poles or trees with rope or spare cable. The spring connectors prevent progressive shortening of the cable from the speaker due to repeated cutting and stripping of the end of the cable.

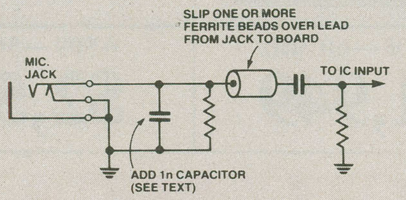
RF INTERFERENCE SUPPRESSION — TECHNIQUES

Public address amplifier systems may be prone to RF interference from a variety of sources — and the source may be unknown or hard to track down. Sometimes the source is well known but impossible to eliminate — a nearby AM broadcast transmitter, for example. CB or marine transceivers in the vicinity of a PA system are notorious sources of annoying intermittent interference. But it's not the fault of the 'offending' transmission; the characteristics of modern solid state devices are the major culprits.

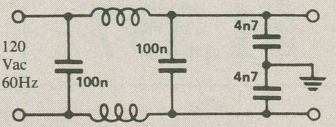
A number of techniques can be employed to protect a PA amp from interference. As it will depend on the individual application, we leave it to the constructor how much, or how little, interference protection to incorporate.



Adding interference suppression on the power input. The value of each capacitor may be anything between about 4n7 and 100n. They should be rated at 630 V or 1 kV.



Adding RF suppression to the low level inputs.



Circuit of a power input filter. The chokes should have an inductance between 5 mH and 50 mH and be capable of carrying up to 2 A. The capacitors may be ceramic types rated at 630 V or 1 kV.

THE 'FRONT END'

The low-level input stages are particularly prone to RF pick-up. There are two components you can add quite simply to protect each low-level input. Firstly, a ferrite bead can be slipped over the lead running between the jack socket and the pc board. Secondly, a 1n capacitor can be soldered directly across the input jack socket terminals. If the leads of this capacitor are cut to a length of 25 mm, the capacitor will have a broad series resonance around 27 MHz, greatly aiding suppression of CB and marine radio interference. These components may be added to both MIC 1 and MIC 2 inputs.

For the AUX input, a capacitor with a value between 2n7 and 10n should be used.

THE 'BACK END'

Long runs of loudspeaker cable have the annoying tendency to act as antennas. 'Choking off' the RF once it gets on a cable run can be problematical. One of the most effective methods is to wind that part of the cable nearest the amplifier speaker terminals on a ferrite rod — such as is used for transistor radio loopstick antennas. This makes a very good broadband RF choke, but it must be installed as close to the amplifier output terminals as possible. There's nothing critical about it, but the ferrite rod should be at least 100 mm long, preferably longer. Ferrite rod in 200 mm lengths, 9.5 in diameter, is commonly available and quite suitable for the application.

POWER LINE INTERFERENCE

Apart from radio interference coupled into cables, light dimmers, motor controllers and switch contacts on equipment connected to the same line as the PA amp can cause a variety of clicks, pops and buzzes to be heard on the system. Proprietary filters can be obtained and often prove very effective. Alternatively, you can build a filter into the PA amp.

One of the simplest suppression methods is to connect a 10n/630 V ceramic capacitor from each side of the transformer primary to the chassis — at the same point. Three-pin plugs can be obtained with capacitors installed and may be quite effective. A 'pi' filter can be built up, as shown in the accompanying circuit, and installed in the amp's chassis.

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Into Digital Electronics Part 10

Ian Sinclair puts shift registers through their paces, and looks at adding circuits.

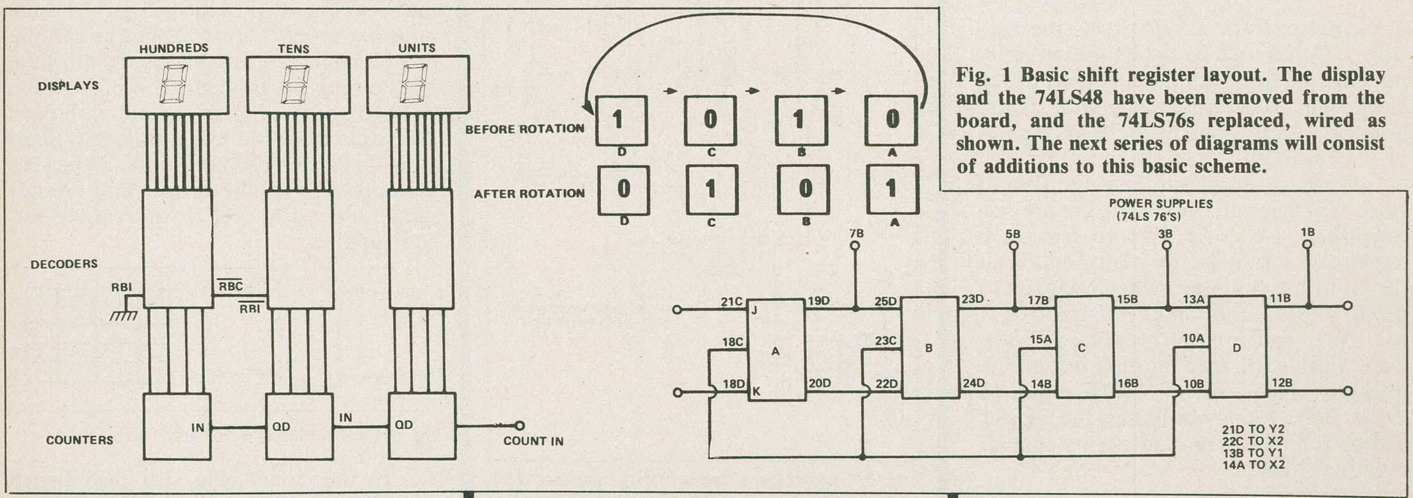


Fig. 1 Basic shift register layout. The display and the 74LS48 have been removed from the board, and the 74LS76s replaced, wired as shown. The next series of diagrams will consist of additions to this basic scheme.

LAST MONTH we looked at the various types of shift registers. Now we can implement them using the 74LS76 circuits which we already have.

To start off with, then, place the two 74LS76 ICs back on the breadboard. Integrated circuit ICA should have its pin 1 in line 10A and pin 16 in line 10B and ICB should have its pin 1 in line 18C and pin 16 in line 18D. We'll need the 74LS132 as well, with its pin 1 on line 19A and pin 14 on line 19B. The power supply connections are as shown in Fig. 1 and all the switches are connected conventionally.

With these preliminaries over, we can start. The board should now contain the three chips, with power supply links, but no interconnections. Link up the J and K inputs to the Q and $\overline{Q}$ outputs in the usual form of a shift register (Fig. 1) and we now have the basic unit which we'll use to demonstrate all the types of shift register.

Start off with SISO. For this one we want to be able to place bits in serially at the input of F/FA. To do this, we need an inverter between JA and KA, and one of the gates of the 74LS132 can be pressed into service for this task. We'll use a switch to clock the register, SW1, and another of the gates of the 74LS132 is used as a simple debounce circuit for the switch. Switch SW2 is now used to provide the serial input, and LED4 indicates the serial output at QD (Fig. 2).

With four flip-flops in the register, any bit placed at the input using SW2 should need four clock pulses from SW1 to complete its movement through the shift register. We must first ensure that all the flip-flops are cleared, and that SW3 has been arranged to do this.

With the circuit wired as shown, turn on the 5V supply, and reset all the flip-flops, using SW3. Switch SW2 up to place a 1 on the input, and operate SW1 once to shift this 1 to QA. Switch SW2 down so that the input now remains at zero, and operate SW1 three more times. This should result in a 1 appearing at the output (LED 4).

The PIPO shift register needs a different set of switch connections, but the NAND gates are not required. Three switches, SW2, SW3, SW4 are used to set the flip-flops, and onto reset (SW1). The switches have been deliberately arranged so that no flip-flop can have both set and reset terminals grounded simultaneously (Fig. 3).

All four of the LEDs are now used to indicate the state of the register, LED 1, for flip-flop A, 2 for B, 3 for C and 4 for D. With the wiring shown, reset by pushing the slider of SW1 down.

Push the sliders of switches SW2, 3,4 so as to select one flip-flop to set — Fig. 4 shows how the switches are set for each flip-flop. Switch SW1 is then pushed up to set that flip-flop. Unless SW1 is pushed down again, the flip-flops which have been set, indicated by the LEDs, will remain set — which is the principle of the PIPO register. We haven't used clock pulses — for this sort of application we don't need them.

Next on the list is the PISO. With our ration of four switches, we can't set the flip-flops individually and still have the register free to be clocked. Figure 5 shows the circuit, SW3 and 4 are used for setting, and SW2 selects set or reset. Switch SW1 lets you isolate the set and reset so that the register can be clocked, using the slow clock pulse generator formed by one of the 74LS132 gates. Indicator LED4 is used to show the state of QD which is the serial output JA = 0, KA = 1, so that the first flip-flop is reset when the clock pulses start. This ensures that the register is emptied by four clock pulses. One of the NAND gates is connected so that clocking starts when the set inputs are isolated.

Wire up, switch on, and use SW2 (down) and SW1 (down) to reset the flip-flops. Now switch SW1 up to isolate the set/reset inputs, and SW2 up to select set. Switches SW3 and SW4 can now be arranged so that either 1 and 3 or 2 and 4 will be set when SW1 is pushed down again. Whenever SW1 is pushed up again, the clock pulses will start to operate the flip-flops, and the bits which have been set will shift right at each clock pulse. After four clock pulses, all the original bits have been shifted out (remember that some of the original bits were zero) and the register is filled with zeros.

The SIPO shift register is easier on switches (Fig. 6). This time each LED shows the state of one of the flip-flop outputs, and the 'signals' are fed in at each

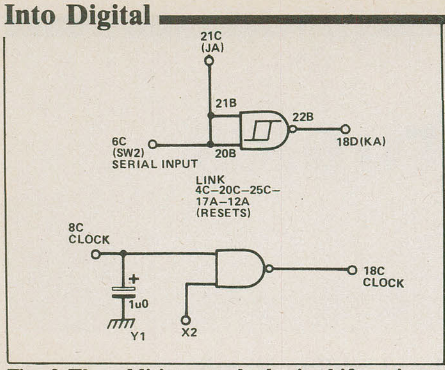


Fig. 2 The additions to the basic shift register circuit for implementing a SISO register.

clock pulse. Switch SW4 resets the flip-flops, SW1 is used to switch the serial input high or low, and SW2 is used as the clock pulse generator, along with its debouncing circuit, one of the NAND gates of the 74LS132.

Wire up, switch on, and use SW4 to reset, so that all of the LEDs are extinguished. Now use SW1 to place a 0 (down) or 1 (up) at the input, and load this in with a complete switch cycle (up to down) of SW2. Pick another value (0 or 1) for SW1, and use SW2 again. At each load, a value will feed into F/FA, and the previous value will be shifted along to F/FB. After four clock pulses, the register will be full, ready to read out its content over four lines.

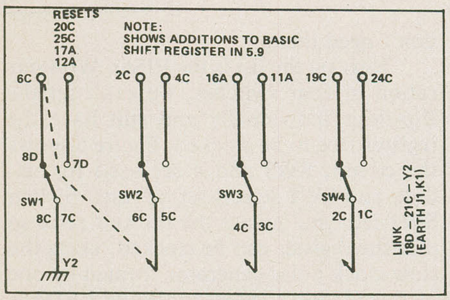


Fig. 3 The switch modifications for a PIPO register. The connections made in Fig. 2 must be removed first.

SWITCH POSITIONS				–SETTINGS–			
SW1	SW2	SW3	SW4	A	B	C	D
L	X	X	X	0	0	0	0
H	H	X	H	1	0	0	0
H	H	X	L	0	1	0	0
H	L	H	X	0	0	1	0
H	L	L	X	0	0	0	1

Fig. 4 Table of switch operations for Fig. 3.

By now we've covered most of the really important basic digital circuits with one important exception — the adder.

The simplest adder is called the half-adder, and its truth table is shown in Fig. 7. It has two inputs, labelled A and B, and two outputs, labelled S (for sum) and C (for carry). Two ways of making a half-adder are shown in Fig. 8. One uses standard gate units, the other makes use of an AND gate along with a type of gate called the exclusive – OR (X – OR). The X – OR gate has almost the same logic as the OR gate, but does NOT give 1 at its output when both inputs are at 1 (that's what it excludes). Its symbol and truth table are shown in Fig. 9. The X – OR gates are available in IC form: an example is the 74LS86 quad X – OR gate.

The action of the half-adder is quite simple. Bits at the two inputs A and B are gated so as to produce outputs at S and C. The bits aren't actually added in the sense of being joined up, but the outputs are the values you expect from binary addition.

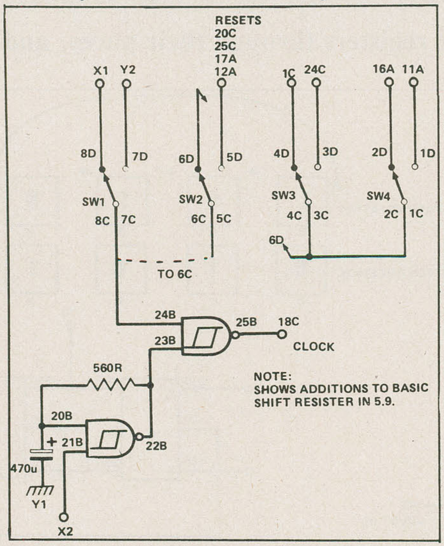


Fig. 5 Connections for a PISO register. The connections shown in Fig. 3 are removed: the diagram shows the additions to the basic circuit in Fig. 1.

For example, with both inputs zero, S and C are also zero. If either input bit is 1, then S = 1 and C = 0. If both inputs are 1, then S = 0 and C = 1 because in binary 1 + 1 = 10 (C is 1 and S is 0).

A half adder can be used only for the lowest bit of two numbers; there is a third bit to add in, the carry from the previous addition. For example, when we add 11 and 11, then the lowest bits add to give a sum of 0 and a carry of 1. The next addition is of bits 1 and 1 with a carry of 1, so that the final result is 110. In denary, just in case you're wondering, these numbers are 3, 3 and 6.

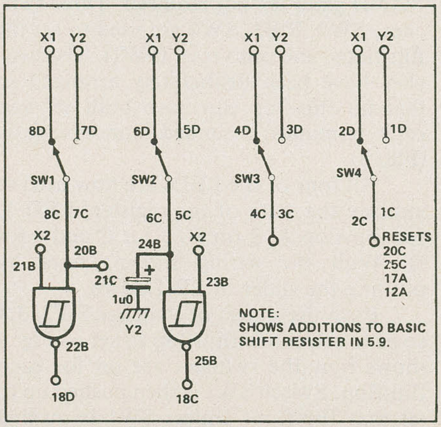
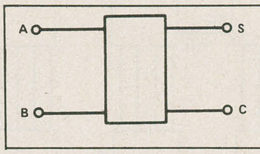


Fig. 6 The SIPO register connections. Once more, this shows the additions to the circuit in Fig. 1, with previous additions removed. This also restores the switches to normal operation for the next set of operations to be described next month.

A circuit which carries out the function of a full adder is a bit more complicated than the simple half-adder. Figure 10 shows a full adder circuit, one half of the circuitry inside the 7482 adder. Each half consists of seven AND gates, an OR gate and an inverter. The inputs are the binary digits A and B, with a carry-in C0; the outputs are the sum S and carry-out C1. The truth table for the full-adder is shown in Fig. 11.

We can set up an adding circuit on the breadboard, with the help of the usual range of switches and LEDs. The 74LS82 two-bit adder is a suitably gentle introduction to binary arithmetic; if the 74LS82 is hard to come by then the old fashioned 7482 can be used in place, though it takes a higher current (about 17 mA). When it's the only chip on the board, that doesn't matter too much, even if you're using battery supplies.



A	B	S	C
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

Fig. 7 Half-adder symbol and truth table.

In the circuit (Fig. 12) each switch contributes a binary digit. Switches SW1 and 2 give one number, with SW1 giving the higher digit and SW2 the lower. Switches SW3 and 4 are used for the second binary number, with SW3 for the higher digit. The outputs are indicated by the LEDs — LED2 shows the highest digit, the carry from the second stage of addition, with LED3 showing S2 and LED4 showing S1. The LEDs will therefore indicated the binary output if you read them from left to right.

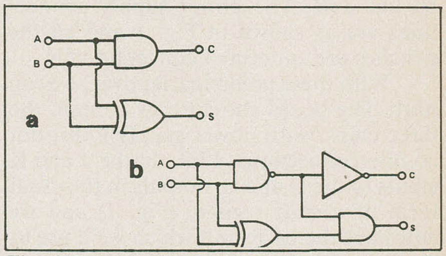


Fig. 8 Two circuits which carry out the half-adder action.

Set 'em up, Joe, and adjust the switches as shown in Table 1, completing the table of outputs for C = 0, which will be the truth table for two bits of addition, with no carry-in. Once you've completed that, change the link at line 14C transferring it from Y2 to X1 so the C0 is at logic 1. Now try the truth table again, filling in the columns under C0 = 1 this time. If you want to see the results in decimal form, you can plug the 74LS48 decoder and the seven-segment display on to the board (replacing the 74132 and the 74LS76) and connect the lower (A,B) pins of the

decoder inputs to the S1 and S2 outputs of the 7482, with input C coming from C2, as shown in Fig. 13)

Multiplexing

There are two other types of circuits that are worth knowing about, though we're not going to use them in this set of exercises. They are both combinational circuits, using gates, and they have a wide range of uses. Figure 14 shows the internal circuit of the 74LS157, which is a quad two-to-one line selector or multiplexer. The inputs consist of pairs of binary digits

A	B	Q
0	0	0
0	1	1
1	0	1
1	1	0

Fig. 9 X-OR gate symbol and truth table.

1A, 1B or 2A, 2B or 3A, 3B or 4A, 4B. There is also a select input and a strobe input.

The strobe input is a 'shut-off' input. With the strobe input high, the outputs are low whatever the input voltages are, so that this can be used to select a zero output. With the strobe input low, the select input can be used to decide which input is connected to the corresponding output. With the select input low, each Q output is the same as the corresponding A input, and the B inputs are ignored. When the select input is high each Q output is the same as the corresponding B input, and the A inputs are ignored. We can use this circuit to select either one of the two four-bit numbers to appear on the output pins, or we can reset the outputs to zero by making the strobe input high. The 74LS157 is a comparatively simple

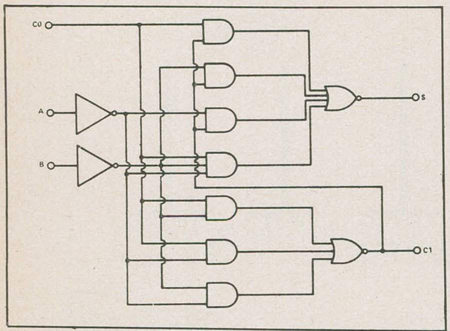


Fig. 10 Circuitry for a full adder. Inputs are the bits to be added, plus a carry from the previous stage: outputs are the usual sum and carry bits.

multiplexer, and some of the more complex types are even more interesting. The truth table and pinout of the 8230 are shown in Fig. 15. This IC uses eight inputs, any one of which can be selected by the voltages of three 'address' lines, A0 to A2, to appear at the output. An inhibit 1 input will cause the output to be zero for any other inputs. The idea of using three address lines to switch the output eight ways is an important one, and it's used a lot in microprocessor circuits.

A	B	C0	S	C1
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

Fig. 11 Truth table for a full-adder.

Demultiplexing

A demultiplexer does exactly the opposite. It has a few inputs which can be switched to a large number of outputs. The 74LS138 is our example, whose pinout and truth table is shown in Fig. 16. The inputs labelled A_0, A_1, A_2 are address or select inputs, and the inputs labelled $\overline{E}_1$, $\overline{E}_2$, E_3 are enable inputs. When either of the E inputs is high, all of the eight outputs will be high no matter what address voltages (0 or 1) are placed on the address/select pins. Similarly, if E_3 is low, the outputs will all be at logic 1. With E_3 high and both of the E inputs ($\overline{E}_1$ and $\overline{E}_2$) low, one of the

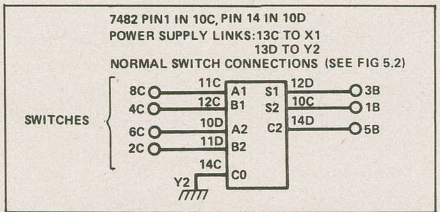


Fig. 12 Using the 74LS82 full-adder. The switches provide the inputs, and the LEDs provide the outputs. The 74LS132 can be removed if desired.

outputs will go low. Which one? That depends on the voltages on the address pins, and the truth table shows which output pin will go low for various addresses. Notice that the address pins have been labelled so that the binary number represented by taking the pins signals in A_2, A_1 A_0 order is also the number of the output. For example, with A_2 = 0, A_1 = 1, A_0 = 0, the binary number is 010, decimal 2, and it is 2 which is low when this address is selected. Similarly when A_2 = 1A_1 = 0 A_0 = 1 (decimal 5), 5 is selected as the low output.

The demultiplexer is a very useful decoder of binary numbers into single lines: the most common numbers of lines are four (two address lines), eight (three address lines) and sixteen (four address

WORD A	WORD B	SWITCHES 1	2	3	4	C0 = 0 C2 LED3	S2 LED2	S1 LED1	C0 = 1 S1 LED1	C2 LED3	S1 LED1
0 0	0 0	L	L	L	L						
0 0	0 1	L	L	L	H						
0 0	1 0	L	L	H	L						
0 0	1 1	L	L	H	H						
0 1	0 0	L	H	L	L						
0 1	0 1	L	H	L	H						
0 1	1 0	L	H	H	L						
0 1	1 1	L	H	H	H						
1 0	0 0	H	L	L	L						
1 0	0 1	H	L	L	H						
1 0	1 0	H	L	H	L						
1 0	1 1	H	L	H	H						
1 1	0 0	H	H	L	L						
1 1	0 1	H	H	L	H						
1 1	1 0	H	H	H	L						
1 1	1 1	H	H	H	H						

Table 1

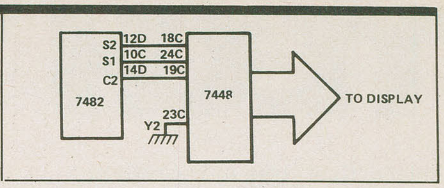


Fig. 13 Connecting the adder outputs to the 74LS48 decoder so that results can be displayed in denary if wanted. The D input of the decoder must be grounded.

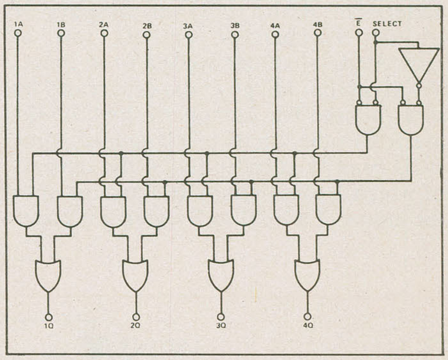


Fig. 14 Internal circuitry of the 74LS157. This is why we use ICs!

ADDRESS			DATA INPUTS									OUTPUTS	
A2	A1	A0	I7	I6	I5	I4	I3	I2	I1	I0	INH	f	$\overline{f}$
0	0	0	x	x	x	x	x	x	x	1	0	1	0
0	0	1	x	x	x	x	x	x	1	x	0	1	0
0	1	0	x	x	x	x	x	1	x	x	0	1	0
0	1	1	x	x	x	x	1	x	x	x	0	1	0
[illegible]	0	0	x	x	x	1	x	x	x	x	0	1	0
1	0	1	x	x	1	x	x	x	x	x	0	1	0
1	1	0	x	1	x	x	x	x	x	x	0	1	0
1	1	1	1	x	x	x	x	x	x	x	0	1	0
0	0	0	x	x	x	x	x	x	x	0	0	0	1
0	0	1	x	x	x	x	x	x	0	x	0	0	1
0	1	0	x	x	x	x	x	0	x	x	0	0	1
0	1	1	x	x	x	x	0	x	x	x	0	0	1
1	0	0	x	x	x	0	x	x	x	x	0	0	1
1	0	1	x	x	0	x	x	x	x	x	0	0	1
1	1	0	x	0	x	x	x	x	x	x	0	0	1
1	1	1	0	x	x	x	x	x	x	x	0	0	1
x	x	x	x	x	x	x	x	x	x	x	1	0	1

x = EITHER 1 OR 0 (DON'T CARE STATE)

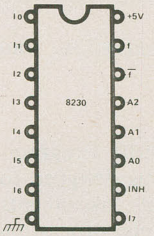


Fig. 15 Pinout and truth table for the 8230 (Signetics) multiplexer.

ENABLE			ADDRESS			OUTPUTS							
$\overline{E1}$	$\overline{E2}$	E3	A0	A1	A2	$\overline{0}$	$\overline{1}$	$\overline{2}$	$\overline{3}$	$\overline{4}$	$\overline{5}$	$\overline{6}$	$\overline{7}$
1	x	x	x	x	x	1	1	1	1	1	1	1	1
x	1	x	x	x	x	1	1	1	1	1	1	1	1
x	x	0	x	x	x	1	1	1	1	1	1	1	1
0	0	1	0	0	0	0	1	1	1	1	1	1	1
0	0	1	1	0	0	1	0	1	1	1	1	1	1
0	0	1	0	1	0	1	1	0	1	1	1	1	1
0	0	1	1	1	0	1	1	1	0	1	1	1	1
0	0	1	0	0	1	1	1	1	1	0	1	1	1
0	0	1	1	0	1	1	1	1	1	1	0	1	1
0	0	1	0	1	1	1	1	1	1	1	1	0	1
0	0	1	1	1	1	1	1	1	1	1	1	1	0

x - 1 OR 0

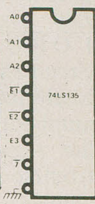


Fig. 16 Pinout and truth table for the 74S138 demultiplexer.

lines). There is also a BCD version, the 74LS42, which converts BCD signals on four lines to decimal outputs (0 to 9) on ten lines.

Next month, we'll look at multiplication circuits, with an introduction to microprocessors. ETI

TECH TIPS

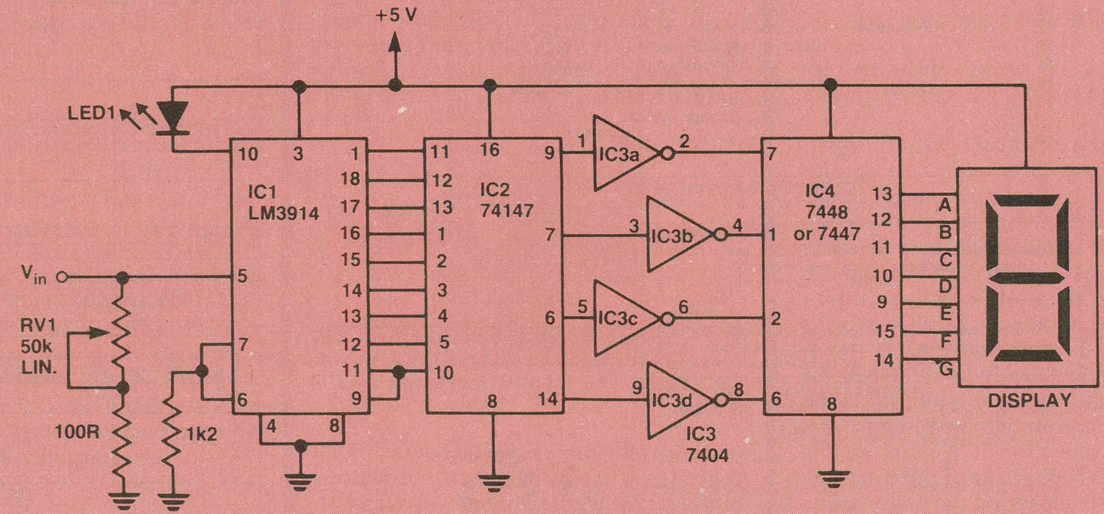
Simple 'flash' type A/D converter
Brian King

The LM3914 dot/bar LED driver is put to use in this circuit to form the basis for a so called 'flash' type analogue-to-digital converter. This device (IC1) will send one of its ten comparator outputs low in response to a voltage applied to its input. Which output will go low is determined by that voltage. The outputs of the LM3914 are fed to the inputs of a 9-line to 4-line BCD priority encoder (IC2), the outputs of which are inverted by IC3 and taken to the inputs of a BCD to 7-segment decoder (IC4). If a voltage is applied to the input of IC1, one of its outputs will go low (as stated before-hand) which, in turn, sends one of IC2's inputs low and its 4-bit BCD equivalent will be set on IC2's output. This is then decoded to 7-segment format, by IC4.

Full scale deflection can be adjusted by RV1. As there are ten outputs from IC1 and only nine inputs of IC2, a LED is connected to the tenth output of IC1 and this effectively functions as an over-range indicator.

The LM3914's outputs change linearly, but if logarithmic changes are needed the LM3915 could be used. It must also be noted that for a full scale deflection of say 12 volts, each output will only change state when the voltage on its comparator input rises at least 1.2V above the previous comparator's threshold.

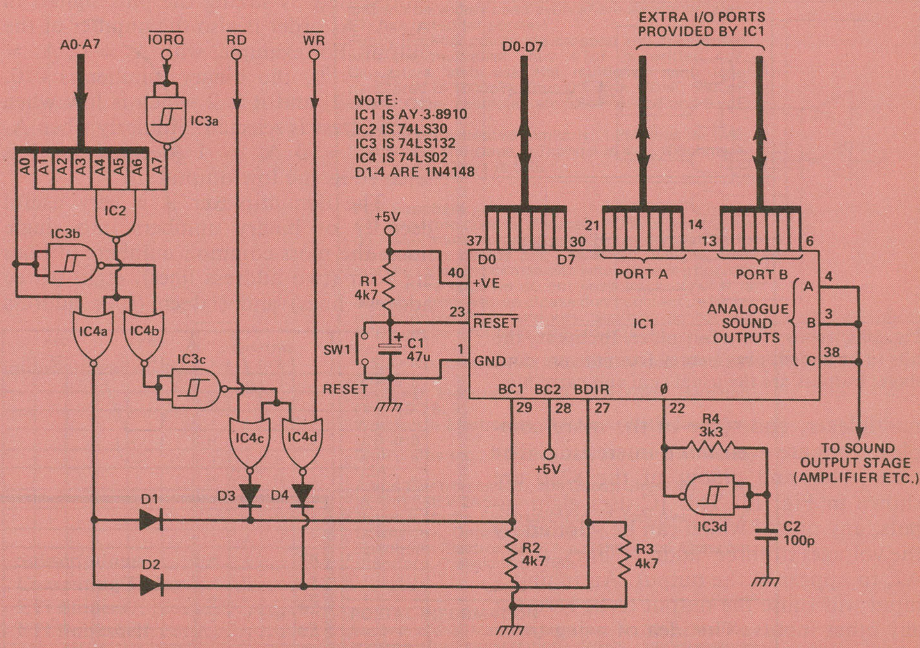
Despite this limitation the circuit could be used for joystick controls (two circuits per stick, leaving out IC4) for computer games, photo print meters, thermometers (where only a scale and not the exact temperature is required); in fact, anything requiring a non-critical one-digit readout from an analogue input.



Programmable Sound Generation And the Z80
Bruce Tanner

Although the GI AY-3-8910 Programmable Sound Generator was designed to be operated with General Instruments PIC 1650 series eight-bit microprocessors or the 16-bit CP 1600/1610, it is easily interfaced to the more widely used Z80. The Z80 signals required are A0-A7, $\overline{IORQ}$, $\overline{WR}$, $\overline{RD}$, and D0-D7. In the circuit shown, one of the PSG's registers is selected by writing the required reigster number to the Z80 port FE (hex) and then the register contents are read/written from/to port FF, although other port numbers may be used by inserting inverters in some or all of A1-A7. In most applications the three PSG audio outputs are connected directly together, although this could be done via manual mixer pots.

The PSG offers three independent oscillators with variable amplitudes, a variable noise source and an envelope generator, all in one 40-pin chip. For more information on the chip operation/functions see the General Instrument data sheet, which is often supplied with it.



Multiflex

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As Featured in ETI Magazine (November 1982)

Basic Kit

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Includes PCB, all parts including 4K RAM (expandable to 8K), ASCII keyboard and 1 RS232 connector.

Case $45.00
Power Supply $45.00
12" Zenith Monitor . . . $145.00*
Modem. 300 Baud, acoustic coupler, attractively packaged . . $55.00*

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Complete Terminal. Assembled and Tested. With power supply and case.

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Now available from MULTIFLEX is an economy video display terminal. Originally designed as a low cost access unit for our soon to be operational computerized mail-ordering and bulletin board system, this terminal is a semi-intelligent system which is controlled by a Z80A microprocessor and a 6845 CRT controller chip. The keyboard is fully ASCII encoded and the character generator contains the full 128-character set as well as a 128-character alternate set both of which are in the 5x7 dot matrix format. The screen display is 80 characters by 24 lines if the unit is hooked to an external monitor (not included) or 64 by 24 if run through an RF modulator to a TV. There are 3 software selectable attributes (dim, reverse video, and alternate character set) which can be chosen one at a time for the whole screen. This attribute can then be switched on and off for each individual character. A 2K buffer is provided for normal operation. However when the optional 6K memory upgrade is purchased, 4 screen pages can be loaded from the host machine, edited locally, and then downloaded back to the host again saving on connect time and phone line bills. Also included are 2 RS232 ports: one for a modem and one so that a printer can be attached to the terminal. The baud rates on these ports are software programmable and can range from 110 to 9600 baud. The MULTIFLEX Video Display Terminal has provision for an on board modem freeing a serial port. With all these features, you would expect to pay a lot for this kit.

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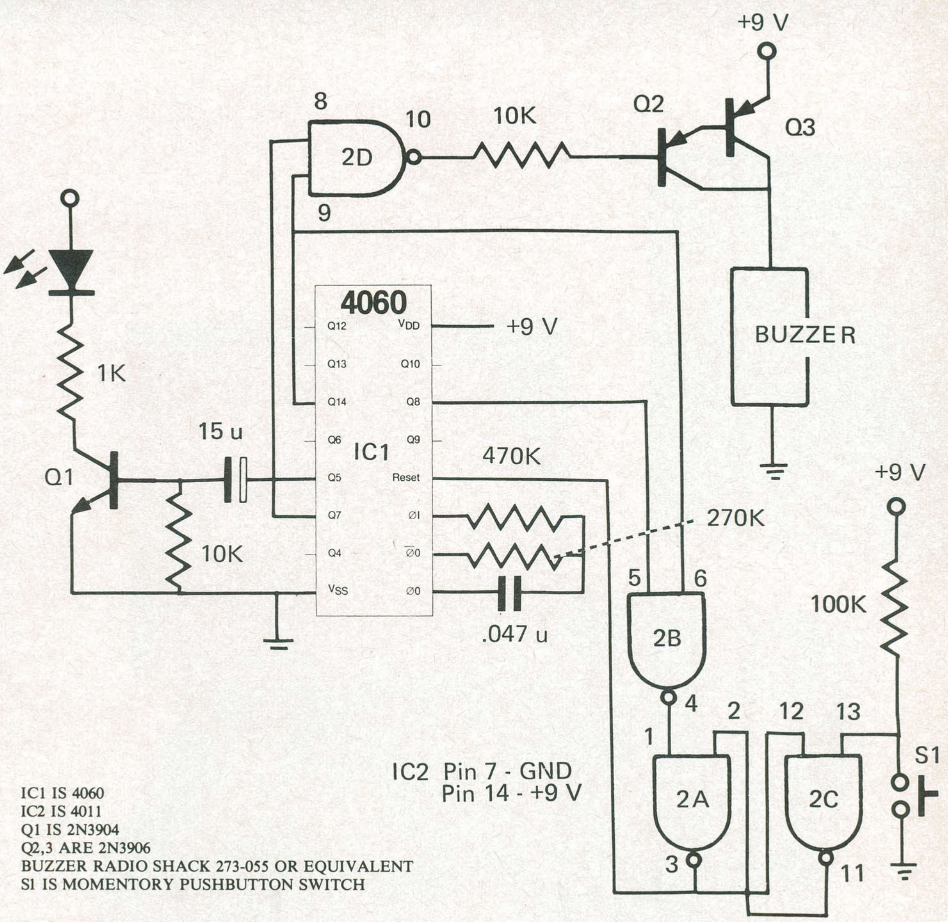
Circle No. 29 on Reader Service Card.

Low Power Timer with Automatic Shut-off

Ed Carew

This timer was designed to replace a 3 minute "hour glass" type timer used for the word game "Boggle". Advantages of the electronic timer are: simple design, automatic shut-off, LED activity indicator, low power and loud "buzz" at the end of timing interval.

The CMOS 4060 is a counter oscillator which can produce long timing intervals with relatively small RC values. With values shown, the buzzer will activate for about 2 seconds at the end of a 3 minute interval. The LED flashes every 3/4 second for the 3 minute duration. Gates B1 and B2 form an R-S latch whch is set by depressing the push button switch, S1. This allows the 4060 reset pin to go low and the counter starts. At the end of the timing cycle (gated Q8 & Q14) the latch is reset and this resets the counter. With the counter reset, current consumption is so low that an on-off switch is not required. Battery life is determined mainly by the shelf life of the battery; my timer has the original battery after nearly two years.



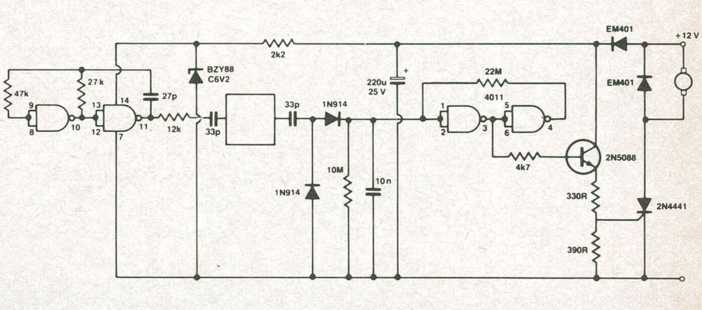
IC1 IS 4060
IC2 IS 4011
Q1 IS 2N3904
Q2,3 ARE 2N3906
BUZZER RADIO SHACK 273-055 OR EQUIVALENT
S1 IS MOMENTORY PUSHBUTTON SWITCH

Touch motor control

L.W. Brown designed this circuit of a touch switch suitable for operating 12 Vdc motors. He says that an excellent use for it would be to mount the touch switch on a shop window, allowing the movement of a display via a car electric fan motor.

An oscillator drives a touch plate stuck to the inside of a glass window. Anything capacitively grounding the 50 mm diameter touch plate causes the Schmitt trigger to turn on the SCR. The 10n capacitor provides several seconds extra operation once the touch plate has been released. As the SCR will latch on with a dc supply, an unregulated, unfiltered supply should be used.

For intermittent operation no heatsink is required and because of this the entire circuit will be smaller than the touch plate. The small size allows the whole switch to be mounted in a sealed plastic box for protection from environmental humidity. The double insulated power supply could enable the system to operate in hazardous locations.



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Sinclair 16K RAM PACK 59.95

Provides massive add-on memory in a compact plug-in module via an edge connector. Can be used for program storage or as database. Yet it costs as little as half the price of competitive memory.

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Designed exclusively for use with the ZX81 (and ZX80 with 8K basic ROM), the printer offers full alphanumerics and highly sophisticated graphics. COPY command prints out exactly what is on screen. At last you can have a hard copy of your program listing and results. Printing speed is 50 characters per second, with 32 characters per line and 9 lines per vertical inch. Connects to rear of ZX81 — using a stackable connector so you can use a RAM pack as well. A 65 ft paper roll, instructions included.

Free catalogue with your purchase of a ZX81 Computer.

Lower price: higher capability.

Sinclair's new ZX81 personal computer is a tremendous advance over the highly successful ZX80. It offers far more computer capability. yet Gladstone Electronics is able to offer the ZX81 at less than half the ZX80 price!

How is it possible? Quite simply, by design. The ZX81 uses only 4 chips (as opposed to 21 in the original ZX80). The secret lies in the totally new Master chip. Designed by and custom-manufactured for Sinclair, this unique chip replaces 18 chips from the ZX80.

The ZX81's advanced capability.

The ZX81 uses the same fast microprocessor (Z80A), but incorporates a new, more powerful 8K BASIC ROM — the "trained intelligence" of the computer. This chip works in decimals, handles logs and trig, allows you to plot graphs, and builds up animated displays. And the ZX81 incorporates other operation refinements — the facility to load and save named programs on cassette, or to select a program off a cassette through the keyboard.

Features.

- Unique 'one-touch' key word entry: the ZX81 eliminates a great deal of tiresome typing. Key words (PRINT, LIST, RUN, etc.) have their own single-key entry.
- Unique syntax-check and report codes identify programming errors immediately.
- Full range of mathematical and scientific funcions accurate to eight decimal places.
- Graph-drawing and animated-display facilities.
- Multi-dimensional string and numeric arrays.
- Up to 26 FOR/NEXT loops.
- Randomize function.
- Programmable in machine code.
- Cassette LOAD and SAVE with named programs.
- 1K-byte RAM expandable
- Full editing facilities.

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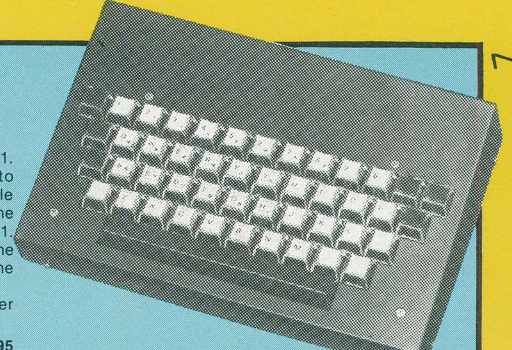
A full-sized professional keyboard for the ZX81. Features 47 keys and a full-sized space bar. Connects to the ZX81 with no soldering required, via a plug-in flexible connector. You can purchase the keyboard only, or the optional metal case that holds both keyboard and ZX81. Expansion devices (i.e. RAM packs, etc) connect to the ZX81 edge-connector which extends from the rear of the cabinet.

A professional keyboard makes program entry easier and less error-prone.

Keyboard K70 . . . .$119.95
Metal case for keyboard and ZX81 E70 . . . .$29.95



NEW

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